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AN INVESTIGATION OF THE REPAIR
CYCLE FOR H-53 AND H-60
HELICOPTER MAIN GEARBOXES--PHYSICAL
MOVEMENT AND INFORMATION FLOWS

THESIS

David B. Noble
Captain, USAF

AFIT/GLM/LSM/89S-45

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT/GLM/LSM/89S-45

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AN INVESTIGATION OF THE REPAIR "PIPELINE" FOR H-53 AND H-60 HELICOPTER GEARBOXES PHYSICAL MOVEMENT AND INFORMATION FLOWS

THESIS

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David B. Noble

Captain, USAF

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The contents of the document are technically accurate, and no sensitive items, detrimental ideas, or deleterious information is contained therein. Furthermore, the views expressed in the document are those of the author and do not necessarily reflect the views of the School of Systems and Logistics, the Air University, the United States Air Force, or the Department of Defense.

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David B. Noble

Table of Contents

List of Figures

List of Tables

Abstract

This study was designed to respond to an AF/LE tasking to examine the pipeline with the goal of determining what information was relevant and what data was used by managers within the pipeline. The study focused on the repair cycles for H-53 and H-60 helicopter main gearboxes. Repair cycles were chosen because they were determined to be the central and most significant portion of the pipeline in terms of management for a reparable component. There were three end products of this research: (1) Maps of the physical movement of assets through the repair cycle; (2) Maps of the information flows within the pipeline; and (3) An analysis of the quantity and quality of information available to managers in the pipeline.

The study methodology was based on the assumption that a map could be traced by extending from a known point in the repair cycle and utilizing the knowledge of the individuals at that point. These individuals were assumed to understand the nature of their interactions with other agencies. It was assumed that by using this incremental method, a macro view of the repair cycle could be traced. Personal interviews and review of relevant management reports and regulations were the specific techniques used.

The research was successful in obtaining its intended end products. Comprehensive maps of both the physical

movem .ts and the information flows were developed for both p elines. Additionally, an analysis of the quantity and quality of information was conducted. It was determined that despite the broad range of computer accessed information available, organizational level maintenance managers still were not provided the information they needed to facilitate their decision making. It was determined that a more effective use of existing databases was possible.

AN INVESTIGATION OF THE REPAIR CYCLE FOR H-53 AND H-60 HELICOPTER MAIN GEARBOXES-PHYSICAL MOVEMENT AND INFORMATION FLOWS

I. Introduction

Background

The United States Air Force Directorate of Logistics Engineering (AF/LE) recently identified "pipeline" management as an "issue of utmost concern" (1:1). At the same time, AF/LE requested research be conducted in this area. Their letter to the Air Force Institute of Technology defined the "pipeline" as including:

> ...the assets which must offset the time involved in requirement computation, procurement, production, delivery, retrograde, repair, requisition, processing, etc. (1:1)

AF/LE identified "policies and procedures" within these functions as having a direct impact on pipeline times (1:1). To show the dramatic impact of the cost savings of reduced pipeline time, AF/LE referenced an Air Force Logistics Command, Directorate of Material Management (AFLC/MM) note estimating the cost of one day of shipping time for recoverable spares at 50.8 million dollars. AF/LE specifically requested a start be made in "getting our arms around" the pipeline. This research effort attempts this start by tracing the physical movement and information flows within a pipeline.

> It would be more productive as a first step, to collectively define the pipeline and piece together what information is regularly collected and used by managers. This will give us insight into what information we don't have. We can proceed from there. (1:1)

This research effort is intended as a contribution to that first step.

The Concept of a Pipeline.

Pipeline inventory has been defined as "inventory in motion, not sitting in a warehouse or in retail outlets" (2:650). Conceptually, in this study, "the pipeline" will also refer to the path inventory takes. The concept of a logistics pipeline provides a useful and illuminating image for thinking about the repair cycle for parts. The physical image of a pipeline works well because it conveys a number of ideas graphically. The first is that the pipeline must be filled before products are available at the other end (2:650). The second idea, the concept of the length of the pipeline, follows directly from this physical image of filling a pipeline. The longer the pipeline, the more parts it takes to fill it and the larger the required inventory. Although there are physical distances involved in the pipeline (parts must be transported from the owning unit to repair facility and back again), the length of the pipeline is usually measured in days (i.e., days of transport time, days of turnaround time at the repair facility, etc.). All considerations together lead to the conclusion that there must be a sufficient stock of spares to cover the daily demand for an item for the number of days the total pipeline process takes.

There are a number of ways to shorten the pipeline. These include faster transport, increased throughput at the repair facility, and changes in the information management system that permit faster processing. There are two basic reasons why we would want to shorten the pipeline. The first is cost. Larger inventories associated with longer pipelines translate to dollars. In the case of components required to support a combat ready Air Force weapon system, the primary issue may not be cost. Our reason for shortening the pipeline in this environment may be that, given a budgetarily fixed inventory of spares, a shorter pipeline increases the availability of combat ready aircraft.

In the case of helicopter gearboxes, the subject of this study, their pipeline contains all gearboxes except those at the manufacturer's plant and those installed on helicopters. The first segment of that pipeline would be the acquisition process that procures the gearboxes from the manufacturer and ships them to the depot where they are stored as spares. The last segment of the pipeline is the salvage/disposition procedure for gearboxes exceeding their useful life or those gearboxes belonging to phased out weapon systems. For this study, the first segment of the pipeline is not within the scope of the study for reasons of focus and the last segment is not relevant for two reasons. The first reason is that H-53 and H-60 main gearboxes are upgraded and modified on a periodic basis. This process, plus their periodic overhaul, effectively extends their useful life indefinitely. Secondly, neither the H-53 nor the H-60 weapon systems will be eliminated from the Air Force inventory in the foreseeable future.

Figure 1 presents a very simplified representation of a pipeline described in business logistics terminology as a "supply chain." As with most business logistics models of a pipeline, this model depicts a linear pipeline. This is because business logistics is usually dealing with consumable products, whose effective life terminates at the consumer. This model would be applicable to Air Force consumable items, a large portion of our overall inventory of supply items. However, the most important components in Air Force weapon systems are reparables. These are items removed from an aircraft, repaired or overhauled on base or at a depot level repair facility, then returned to a storage facility for reissue and reinstallation on an aircraft. This situation creates the repair cycle, a portion of the pipeline for these items that contains several time-consuming subcomponents. For most of the life of a reparable component, the repair cycle is, for all intents and purposes, the pipeline for that component.

Integrated Supply Chain Management

The Concept Simplified

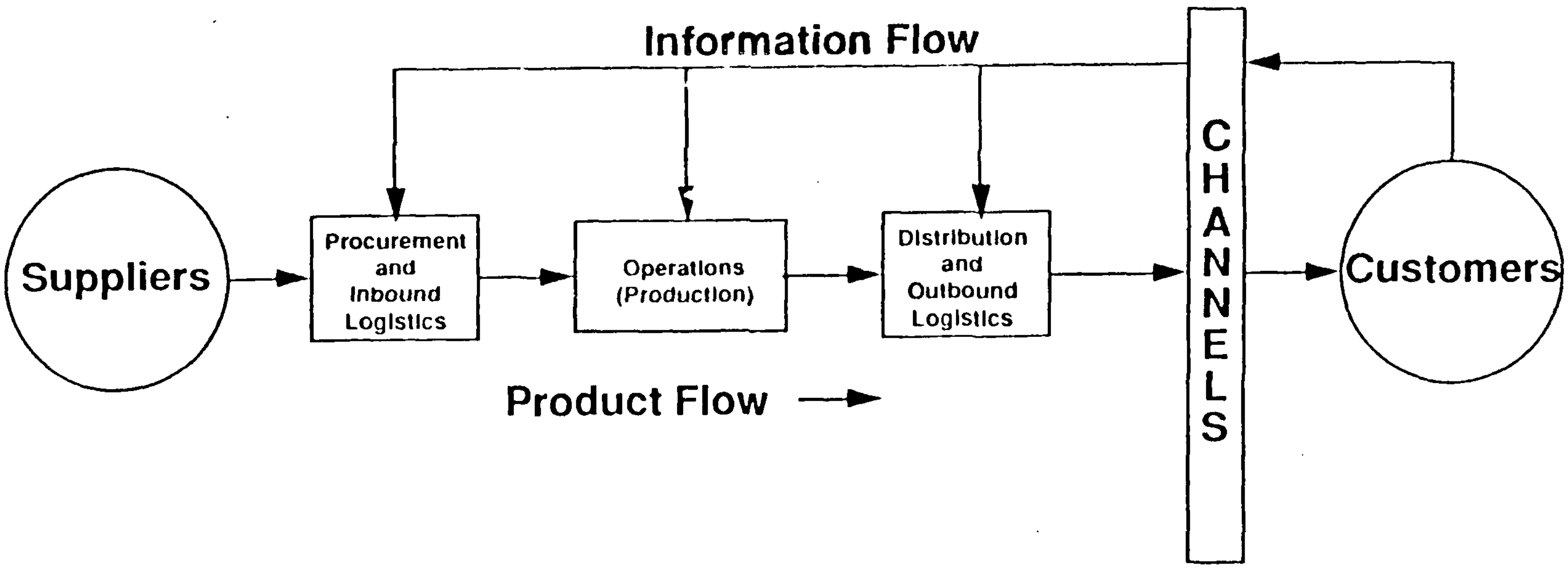

Figure 1. Generic Pipeline

Adapting the model shown in Figure 1, Figure 2 shows the unique nature of a repair cycle. The customer, the using unit for the serviceable gearbox, is also the supplier of the unserviceable gearbox. The repair/overhaul facility overhauls the gearbox to produce a serviceable asset to send to the customer, the using unit. Due to the focus of this study on the depot repair cycle, this discussion has left out the base repair portion of the repair cycle. H-53 main gearboxes are designated as being 13 percent reparable at the base level. In actual practice the amount of base level repair is minimal, involving the changing of seals and other minor corrective actions (36). The H-60 main gearbox is designed in a modular configuration. The maintenance personnel at the organizational level must troubleshoot the discrepancy to one of six modules, remove that module, and send it to depot level repair. Thus, the H-60 has zero base level repair.

Figure 3 places the repair cycle described above in its central location within the overall pipeline. As mentioned above, on a day to day basis, the repair cycle is the operative portion of the pipeline for a reparable component. For reparable components it is the repair cycle that is managed. Procurement actions for spares are initiated when the weapon system itself is in the acquisition phase and then again in response to a long term inability of the repair cycle to produce serviceable components rapidly enough to meet component failure rates.

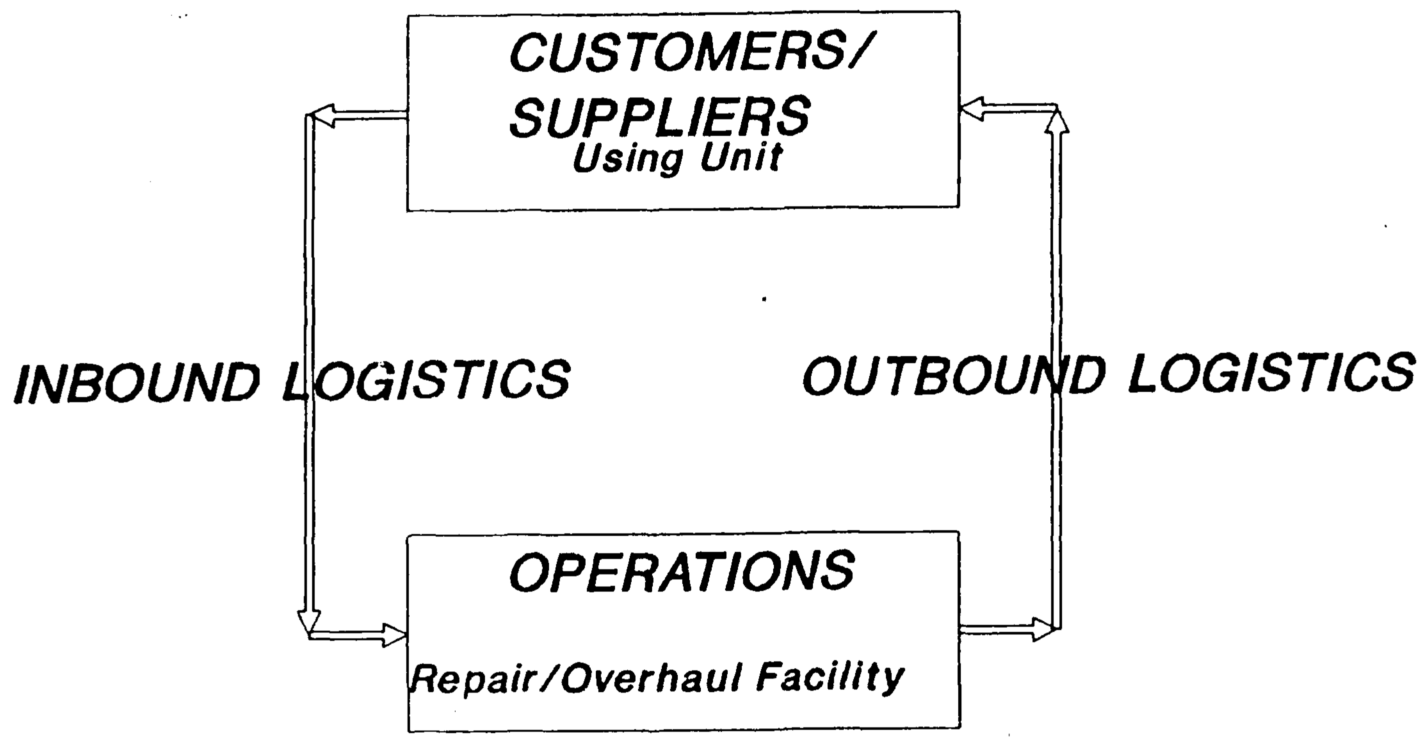

Figure 2. A Generic Repair Cycle

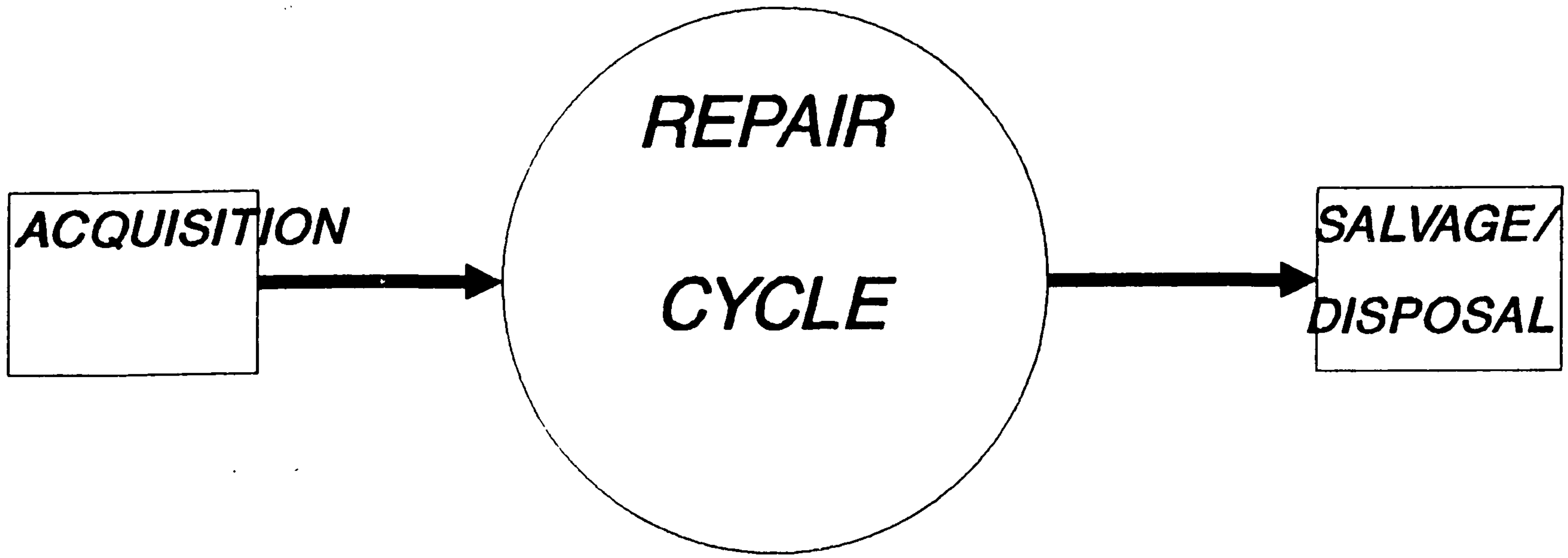

Figure 3. A Simplified Pipeline

But always, the repair cycle is the central, controlling component of the pipeline.

General Issue

What is needed is the incremental construction of a "road map" of the repair pipeline. This depiction will reveal not only the physical movement of parts within the pipeline, but also will trace the information flows within the pipeline. This research will focus on the pipeline for a specific type of mechanical component installed on two specific weapon systems. It is narrowed further to the repair cycle for those components, a portion of their total pipeline that excludes the acquisition and spares stockage of those parts. Special attention will be focused on the information flows within the pipeline, specifically those involved in supply requisitioning, a portion of the order cycle.

Specific Problem:

This research attempts to answer the question "How are H-53 and H-60 helicopter gearboxes managed throughout their repair cycles?" Gearboxes were chosen as components of interest for a number of reasons. First, they are the key mechanical components in the drive train of a helicopter, probably the most mechanically complex of all Air Force weapon systems Where other weapon systems, such as fighter aircraft, have complex avionics systems, the complexity in helicopters resides in their aerodynamic and propulsion systems. Lift generation and inflight movement in a helicopter are dependent on the complex, synchronized interaction of jet engine powered mechanical and hydraulic components. The helicopter's gearboxes are the crucial elements in this drive train. As such, the absence of a serviceable gearbox on a helicopter automatically prevents the helicopter from flying.

Second, with a mission on the low end of the conflict spectrum , helicopters are arguably the most likely system to be employed in the near future. The Air Force mission of both the H-53 and H-60 helicopters is special operations or, more specifically; the infiltration, resupply, and exfiltration of special operations ground forces (Page:67). As one author points out:

> For more than two decades, conflicts short of conventional warfare have threatened U.S. interests around the world. This type of warfare, called low-intensity conflict, has spread so rapidly it now represents the most probable arena for the application of U.S. military force in the foreseeable future. (Page:67)

In recognition of this fact, the U.S. Special Operations Command became a unified commnd on April 16, 1987 (Lindsay:51). MH-60G Pave Hawks and MH-53J Pave Lows are critical Air Force Component assets in this unified command. Additionally, due to their small numbers, a single non-mission capable H-53 or H-60 helicopter has a serious impact on unit readiness.

The third reason for choosing gearboxes is their cost. As an example, the main gearbox on an H-53 helicopter has a value of $127,960.00. Obviously any reduction in required spares for these components would represent a substantial dollar savings. Additionally, the mechanical complexity of these components generates long overhaul times and their large size creates high packing, handling, transportation, and warehousing costs.

The final factor pertains to the specific choice of the H-53 and H-60 weapon systems. These weapon systems share a unique reparable parts pipeline structure. Both systems have a reparable parts pipeline that leaves Air Force logistics channels and extends into the logistics system of another service branch. Since the United States Navy possesses a much larger inventory of H-53 helicopters, their depot repair facility at Pensacola Naval Aviation Depot also is utilized by the Air Force. A similar situation exists for the H-60 helicopter. Since the Army manages an 1100-ship fleet of H-60's (3:1), the Air Force routes its H-60 reparable parts through the Army reparable parts pipeline. This reparable pipeline is further complicated by the contractor repair of the H-60 gearboxes at Sikorsky Products Division of United Technologies in Stratford, Connecticut. Finally, the interface of different policies and procedures and dissimilar information systems between services potentially complicate the management of these pipelines.

Assumptions

The basic operating assumption of this study is that the construction of a "road map" of the pipeline is the necessary first step toward increasing visibility and speeding up the process in order to shorten the pipeline and increase availability of H-53 and H-60 gearboxes. A further methodological assumption is that, by incrementally extending out from a known node (agency) in the pipeline, one can draw the branches of the pipeline and construct a comprehensive map. This process is facilitated by limiting the study to the repair cycle, a piece of the pipeline. Furthermore, this study assumes that small junctions in the pipeline are thoroughly understood by the agencies and individuals that operate across those junctions, although no single agency or individual may possess a "macro" view of the pipeline.

Investigative Questions

The following questions will be used as guides in the construction of a physical and informational road map of the H-53 and H-60 gearbox repair cycles and the investigation of the quantity and quality of the information available to managers within the pipeline.

1. What are the key agencies (nodes) in the physical movement of the gearboxes and how are they linked (arcs)?

2. What are the key agencies (nodes) in the information flow and how are they linked (arcs)?

3. What standard forms/computer inputs and products are used to track assets through the pipeline?

4. What are the respective roles of the key managers in the pipeline?

5. Are the available information products useful tools for managers in the pipeline?

6. What problems exist in the interface between the Air Force and Navy supply systems for H-53 gearboxes?

7. What problems exist in the interface between the Air Force and Army supply systems for H-60 gearboxes?

8. What problems exist in the transfer of information within Air Force logistics channels?

Scope and Limitations of Research

Focusing this study on a single reparable component would result in too narrow a study. Too broad a sample of components, however, would make the map too complex and violate the incremental strategy of the study. Any one study in the AF/LE mandated research effort is not capable of "swallowing whole" a large portion of a very complex pipeline. With these considerations in mind, this study examines a specific class of mechanical components. It further is restricted to components of this type found on two specific weapon systems, the H-53 and H-60 helicopters. Finaly, it is confined to the repair cycle for those components, a portion of their overall pipeline that excludes the acquisition and spares stockage of those parts.

Summary

This study, as described, is concerned with the repair cycle for two reparable components, the H-53 and the H-60 main gearbox. As reparable components, their repair cycle is the central portion of their overall pipeline. This repair cycle consists of both a physical movement of assets and the information flows that direct and monitor the gearboxes as they move through the pipeline. Shortening that pipeline in terms of the days required to perform the overall repair cycle process is of great interest because, given a fixed number of assets, a shorter pipeline will mean greater weapon system availability. Knowledge of actual pipeline processes is essential to controlling and shortening the pipeline. Understanding the H-53 and H-60 main gearbox reparable pipelines is the prime goal of this study.

The following chapter offers a review of the literature on pipelines, repair cycles, and order processing. The literature is found in business logistics books, business logistics periodicals, and military periodicals.

II. Literature Review

A Systems Approach

It has been said that "The logistics process is best understood when viewed as a system" (14:1). Systems theory has become a key conceptualization tool in a broad range of disciplines including logistics. Benjamin S. Blanchard, a foremost logistics theorist, claims:

> The experience of recent decades indicates that properly coordinated and functioning man-made systems, with a minimum number of undesirable side effects, require the application of a well-integrated "systems" approach. (3:xi)

He defines a system as "a set of interrelated components working toward some common goal" and points out there are, in fact, systems within systems, with one system being a subsystem of some larger system in a hierarchical structure (3:4).

Blanchard further emphasizes the importance of establishing a clearly defined objective. Without a clear idea of the system objective, there is no benchmark against which to evaluate its performance (3:4). Finally, he depicts the systems approach as a "top down" approach where "attention is first directed to the system as a black box that interacts with its environment" and then the subsystems within the larger system are identified along with their interactions (3:6). This chapter examines the interaction of the pipeline subsystems in pursuit of the system objective, supplying components to return an aircraft to an airworthy status where it is available to perform its mission.

My discussion will begin by defining military logistics in a manner that places it squarely in the larger system of American warfighting capability and describes its objective within that system. The objective of military logistics is "the support of combat forces;" and it fulfills this objective in the overall system of American warfighting capability as "the central component that links strategy and tactics to give a warfighting capability" (44:1).

Moving down one step in the hierarchy from the system of military logistics, we must now consider the pipelines that support each individual weapon system. These pipelines, as described in Chapter II, are the paths that a component takes, beginning with its acquisition as an installed part of a weapon system and ending with its eventual salvage/disposal. Actually, there are a myriad of pipelines for each weapon system. An individual pipeline exists for each item that is a component of that weapon system, although similar items may possess identical pipelines. Since H-53 and H-60 main gearboxes are reparable assets, their pipelines contain a unique subsystem that is not part of the pipeline for nonreparable parts. This subsystem is the repair cycle for that part, as described in Chapter I. The repair cycle is the central and most crucial subsystem in the pipeline for a reparable part. Finally, integrated with the repair cycle, is another major subsystem known as the order cycle. This nested structure is illustrated in the framework presented in Figure 4. As this framework indicates, the repair cycle is the central component within the pipeline between acquisition and salvage/disposal. Within the repair cycle, the order cycle operates between the using unit and the storage facility. After the gearbox is removed from the aircraft for repair/overhaul, another gearbox is ordered, via a supply requisition, from the storage facility. The storage facility is, in turn, the recipient of the serviceable gearboxes coming from the depot repair facility. This literature review will proceed to describe these systems from the top down, starting with the pipeline.

The Pipeline

The basic concept of a pipeline was explained in Chapter I. At this point we will look at the kinds of inventories that make up a pipeline. If the pipeline consists of "inventory in motion" (2:650), there are three types of pipeline inventories: intransit inventories, inventories to allow stock-mixing or consolidation, and inventories to provide a buffer for replenishment lead times. These inventories exist in each pipeline to a different extent. One way to quantitatively analyze the impact of pipeline inventories is to measure them in terms of days. The number of days multiplied by daily demand,

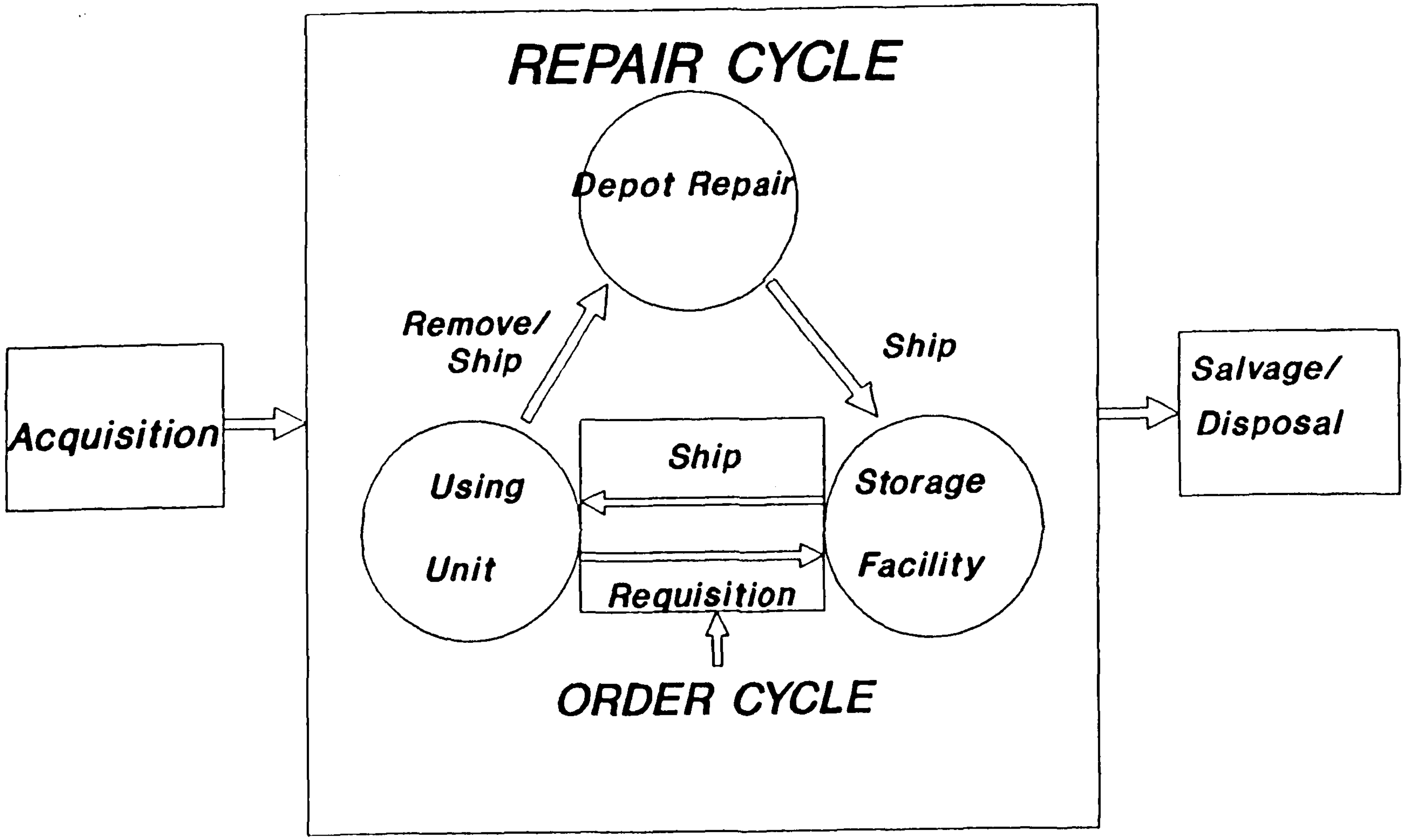

Figure 4. Pipeline/Repair Cycle/Order Cycle

yields the number of assets required in the pipeline to ensure an asset is available whenever it is needed (12:651). Each type of pipeline inventory can be analyzed in this manner.

Intransit inventory can be reduced directly by shortening transportation time. The simplest way to shorten transportation time is to use a faster mode of transportation. In almost all cases, this means increased transportation costs. However, the increase in transportation cost must be traded off against the savings in inventory costs because of the reduction in intransit inventory (12:652).

Inventories that permit stock-mixing or consolidation also involve trading inventory costs off against reduced transportation costs. These inventories are driven by an effort to reduce transportation costs by taking advantage of the lower rates associated with larger volumes shipments. In this case, the savings in transportation costs are traded off against the inventory costs associated with holding shipments in a warehouse as they wait to be consolidated into a larger shipment (12:654).

The "lead times" referred to in replenishment lead times are not driven by the time it takes to transport a shipment. They are the lead times associated with processing an order. "In addition to pipeline inventories related to physical time lags, there are also pipeline inventories caused by information time lags" (12:655). Information time lags can be reduced through improved communication and information processing systems. Implementation of new systems is expensive, but their cost must be traded off against the savings realized by reducing inventories. Not all information time lags call for new systems, however. Many can be reduced by simplifying the existing systems.

Of the three types of pipeline inventories, those caused by information time lags may be the most easily examined within the Air Force logistics system.

The Repair Cycle

AFM 67-1, Volume II describes the initiation of the repair cycle for a reparable item:

> The repair cycle of a malfunctioning item begins with the item's removal from an aircraft or item of equipment. Removal is followed by a request to Base Supply for a replacement. (7:239)

In the discussion that follows this statement will be shown to include, in close temporal proximity, the initiation of the repair cycle as well as the initiation of the order cycle that is its subcomponent.

AFLCR 57-4, the handbook for the Repair Requirement Computation System (D073), defines the depot repair cycle as "the timespan, expressed in calendar days, from the time an unserviceable item is removed from use until it is ready for use" (10:1-9). The D073 system, from its serving databases, provides actual parameters based on computed averages, as well as standard times, for the five components it divides the depot repair cycle into: " base processing days" (processing of a reparable off base), "reparable intransit days" (transportation to the repair facility)," supply to maintenance days" (inprocessing at the repair facility)," shopflow days" (actual repair/overhaul time), and "serviceable turn-in time" (processing of the reparable out of the repair facility, transportation to the storage facility, and inprocessing at the storage facility) (10:1-3 to 1-4). AFLCR 57-4 then defines "order and shipping time" as the time from initiation of a request for a serviceable item to receipt of that item at the requesting activity" (10:1-7). This time interval was previously referred to as order cycle time. Conceptually, this study views the order cycle as a subsystem integrated with the repair cycle.

For the purposes of this study, "the repair cycle" is defined as the cycle of processing a reparable asset through the owning unit host base supply function, transporting it to the depot level repair facility, processing it into the repair facility, repairing it, processing it out of the repair facility as a serviceable asset, and transporting it to a storage area. This definition is merely a further elaboration of the AFLCR 57-4 analysis discussed above.

The order cycle begins with a supply requisition from the using unit for that reparable. The request is processed through host base supply for that using unit and transmitted electronically to the storage facility where the requisition is processed, the serviceable asset is prepared for shipment,and then shipped to the using unit host base supply where it is inprocessed and made available for issue to the using unit. It should be noted repair cycle and order cycle operate simultaneously. LaGrange addressed the impact of the repair cycle on combat sustainability in the context of US Army tank repair in a combat environment. LaGrange initially distinguished between permanent and temporary losses of weapon system assets. Although no specific criteria were cited, the implication was that a permanent loss was caused by severe battle damage and would result in asset recovery outside of the battle area. A temporary loss would be less severe and would be repaired by organic maintenance not far from the forward edge of the battle area. Permanent losses, on the other hand, are depicted being replaced by war reserves and new procurement; that is, from outside the repair cycle. Temporary losses were shown as replaced through the repair cycle(8:10).

LaGrange then compared temporary loss rates to permanent loss rates for tanks in the 1973 Israeli conflict. In a six month period there were 18,000 temporary losses and 6,000 permanent losses, yielding a 3 to 1 ratio in favor of temporary losses (8:11). La Grange cites other systems, said to show up to a 10 to 1 ratio. The author concludes:

> Without sufficient maintenance equipment, manpower and facilities, a large part of the temporary losses could end up as stagnant backlog, which could create a major backlog...War reserves? Important? Yes! But equally as important is our ability to return temporary equipment losses to the combat forces. (8:11)

In a peacetime environment, the key component in the repair cycle is the depot repair facility. Increasing depot productivity becomes, then, a crucial factor in shortening the repair cycle. Before attempting to increase depot productivity, the unique characteristics of a repair facility versus a normal production facility must be examined.

Of the three levels of maintenance, organizational, intermediate, and depot, the depot function is most like a production function and, therefore, amenable to modern productivity enhancement techniques. Still, the differences between a repair function and a production function make the task relatively more difficult (1:14). First, depots have an inherent scheduling problem. Where production usually is performed in predetermined runs or batches, depot repair must be done sporadically. Repair rates can be predicted, but the degree of variability is high as "... failures cannot be predicted accurately enough to formulate a workable schedule" (1:14).

Repair facilities also must deal with the inventory management problems caused by the variability in failure rates. This is compounded further by the permutations and combinations of parts requirements caused by the failures of sub and sub-sub components.

Finally, the depot repair operation is inherently discontinuous because of the unpredictable arrival of reparable assets and frequently changing priorities (1:14).

In the final analysis

> Even the most efficient repair facility will never be able to approximate the output of the average production facility due to the inherent differences and problems previously outlined (1:19).

The Order Cycle and Order Processing

The Nature of the Order Cycle and Order Processing.

Order processing as a crucial element in the distribution of goods has received a very high level of attention in the business logistics literature in the 80's. As businesses attempt to reduce costly inventory by shortening their pipelines, they have targeted the order cycle as a component in the pipeline system where efficiency can be readily increased. Coyle and Bardi(1976) defined order processing as "those activities involved with filling customer orders" (9:15). They distinguished order processing from order preparation (getting the order ready to be shipped) and the actual transportation of the order.

Stock and Lambert (1987) (13:499) define the order cycle as "all the elapsed time from the placement of the order until the product is received and placed into the customer's inventory" (13:499). The six components they distinguish are: "(1) order preparation and transmittal (2) order receipt and order entry (3) order processing (4) warehouse picking and packing (5) order transportation and (6) customer delivery and unloading" (13:499). Here, order processing is listed as one of the six components of thr order cycle.

Much of the periodical literature regarding order processing speaks addresses information processing (Stock and Lambert's components (1) through (3)) as opposed to physical activities (Stock and Lambert's components (4) through (6)). This literature review discusses order processing, as it relates to the thesis topic, in terms of the information processing activities within the order cycle.

Recent Developments in Order Processing. In the late 70's and early 80's, the order processing literature pointed to automated order entry systems as powerful logistics productivity enhancers, offering radical improvements over the old, paper-intensive system. Before the advent of automated order entry systems, orders were taken over the telephone from salesmen or customers or, even more time-consuming, were sent through the mail. At the centralized headquarters where these orders were received, other forms were generated and physically moved about from in-basket to in-basket.

This system was not only slow, it had tremendous potential for error. Transcription from a verbal order to paper, or from paper to paper, was a slow, laborious process, with many opportunities for error and a tedium level that further increases the chance of an error. Automated order systems offer vast improvements in speed, as well as accuracy. As evidence of the degree to which the old system relied on paper, one firm cites the elimination of 2,000 paper invoices per week with the advent of an automated order entry system (5:35).

Logistics success stories associated with automated order entry systems are numerous. Among the benefits cited are inventory cost reductions and improved order accuracy. Additionally, management visibility of potential problem areas is a valuable indirect benefit. One system, in place in 1979, was credited with a 60% reduction in inventory (7:83). This system also included an error proofing feature that led the clerk through the order entry process, providing immediate feedback for an erroneous entry. This common integrity feature in automated systems is an important reason for their increased accuracy. A manager praised his new system for the newfound assurance that "items...are hours, instead of days or weeks away" (7:87). Another system, said to have reduced order cycle time by two to six days, was also recognized for increasing management visibility, "Managers can now foresee trouble and minimize or avoid it. In the past, they too often learned about a problem after it had happened" (9:90).

In 1984, a major breakthrough occurred that increased the power of automated order entry systems even further. This was the year that the American National Standards Institute offered its package of standardized electronic entry forms, the ANSI X12 system. The ANSI X12 SYSTEM, which contained versions of the basic distribution forms (e.g., ANSI X12.1 is a standardized purchase order, ANSI X12.2 is a standardized invoice, etc.) enabled cooperating firms to send order information computer to computer via modem with no intermediate transcription (10:98B6 inset). The differences between one firm and another firm's forms had made transcription a necessity in the past. The direct computer to computer link, now facilitated, meant even greater speed and accuracy (and accuracy, of course, translates to speed - no time wasted correcting errors or reinputting information).

The technical term for this direct computer to computer links is Electronic Data Interchange (EDI). Firms have adopted EDI with great enthusiasm. Analysts see EDI growing at a geometric rate (10:98B5). Some even project a 1000% growth in EDI use in the next two to three years (10:98B6).

Development of built-in audit trails will be the last hurdle to acceptance (10:98B5). Proponents of EDI describe its benefits in pipeline terms:

> Let's deal with basic merchandise that a small retailer would order once a month. The transmission time on paper is going to be three to four days. Then it has to get into the order entry system of the vendor where it is going to be waiting along with 2,500 other customers to get into the computer to decide whether the vendor has the merchandise to ship. It may take four days. So we have eight working days right there that every retailer has to add to his supply pipeline to make sure he never runs out (10:114 inset).

Summary

This literature review has taken a systems approach to analyzing the repair cycle. It described the systems approach and demonstrated that the repair cycle can be analyzed by moving analytically from the top down, describing the repair cycle as a component of the overall pipeline for a reparable part and then describing the order cycle as a part of the repair cycle. It has reviewed the literature available in current military and business periodicals on pipelines, repair cycles, and order cycles. The next chapter will discuss the methodology used to answer the investigative questions posed in Chapter I.

III. Methodology

Chapter Overview

This chapter discusses the methods used to obtain answers to the investigative questions raised in Chapter I. The goal is to understand how H-53 and H-60 main gearboxes are managed throughout their repair cycles. The large number of individuals and agencies involved as well as the intricacy of their interactions adds complexity to this effort. The key to dealing with this complexity is to incrementally trace the map outward from a known point. The success of this strategy pivots on the basic research assumption the individuals involved in this process are knowledgeable of their role and those of interconnecting functions. If we can come to understand how assets are managed in the repair cycle and map out the process, then we can analyze that process to learn how to make it more efficient. The ultimate goal is to have more aircraft available to perform the critical special operations mission.

Answers to the investigative questions are intended to yield the two basic end products of this research effort. The first end product consists of comprehensive maps of the physical movement of assets and the information flows within the pipelines. The second is an investigation of the quantity and quality of information available to managers in the pipeline. The chapter examines the data collection method, the structure of the interview instrument, the actual data collection process, and the selection of the research population.

Method of Data Collection

There were three sources of information for this research: personal interviews, by telephone and face-to-face; review and analysis of various computer-generated reports and standard forms used to process or manage assets in the pipeline; and review of relevant regulations. The physical movement map, which provides the answer to Investigative Question 1, was constructed through unstructured telephone interviews. Construction of the information flow map and investigation of the quantity and quality of information within the pipeline provide the answers to Investigative Questions 2 through 8. These were accomplished through unstructured interviews, structured interviews, review of available information products, and review of relevant regulations.

The personal interview technique was the primary method used to develop the pipeline maps and determine what information managers use to manage assets in the pipeline. Eckhardt and Ermann define interviewing as "a data collection procedure involving verbal communication between the researcher and the respondent either by telephone or in a face-to-face situation" and point out that, though the two interview methods differ somewhat, "there are a number of advantages and disadvantages common to personal contact" (9:222).

The advantages of interviewing techniques, both telephone and face-to-face, involve the quality of the information obtained. Emory discusses the "depth and detail of information" obtainable as a result of the ability to ask followup questions and acquire additional information through observation (14:160). This research effort made use of both of these advantages, particularly in face-to-face interviews where reports and forms could be examined and discussed. Emory emphasizes the peculiar advantages of face-to-face interviews. This researcher found face-to-face interviews to possess a uniquely high degree of flexibility that permitted a great degree of "depth and detail of information" Additionally, it was found that telephone interviews, if aggressively pursued with an effort to establish a rapport with the interviewee, were also highly flexible tools for obtaining information.

However, as Emory points out, face-to-face interviews are very costly. Cost was a primary factor in the choice of telephone interviews as the primary method in this research effort. Time was a secondary factor. A crucial problem inherent to all interview techniques must be noted. Emory discusses the tendency for interviewees to report sensitive data in less than perfectly accurate terms. It seemed obvious to the researcher that interviewees would tend to minimize problems with the management systems they worked with on a daily basis. However, as Emory warns, "Consistent control or elimination of such respondent bias is a problem that has yet to be solved" (14:166).

This research effort utilized both face-to-face and telephone interviews and sought to take advantage of their common strengths. A specific strength sought was the "ability to clarify questions or probe for additional information (9:222)." Brenner elaborates further on the flexibility provided by the interview method,

> Any misunderstanding on the part of the interviewer or interviewee can be checked immediately in a way which is just not possible when questionnaires are being completed, or tests are being performed. (4:3)

Because of the exploratory nature of this research, the research method had to be sufficiently flexible to permit the researcher to use further questions to follow up leads suggested by the interviewee.. The personal interview technique provided structure and consistency to the questioning, while also providing this required flexibility. Where the interviews were conducted in person, the researcher could examine actual information products and ask questions as required. These products were a key source of information for the research.

At one level, these interviews constitute a logistics audit, as per Stock and Lambert's concept of a customer service audit. Specifically,the interview process represented a partial internal audit. They emphasized the importance of the internal communications within a businees firm and the role of an internal audit in evaluating these communications

> The communications system largely determines the sophistication and control of customer service within a company. As LaLonde and Zinser stated, "Without good control of information flow within the firm and between the firm and its customers, the customer service function is usually relegated to reporting performance level statistics and reacting to special problems." That is why an internal audit must evaluate the communications flow from the customer to the company and the communications flow within the company . . . The internal audit should give top management a clear understanding of the firm's communications with the customers. (13:137)

In the context of this study, the "firm" is the repair cycle, the "customers" are the using units.

Structure of the Interview Instrument

Wilson lists the following as the first two stages of questionnaire design: determination of the "areas to be explored in the interview" and "question wording and sequence (19:66)." The development of the survey instrument for this research followed this two stage process. Since one of the purposes of this research was to draw a map of the pipeline, a portion of the questions were designed to determine simply where in the pipeline a given individual is located. These questions do this by asking where the indivdual obtains information and where the individual sends information. This method was based on the research assumptions, stated in Chapter I, that one can build a pipeline map by extending out from a known node and also that individuals have a thorough understanding of the junction of the pipeline that they operate across. They know "who talks to them" and "who they talk to"(and "what they talk about").

The final purpose of the interview questions was to understand each node in the pipeline as an information processing system. Questions were designed to determine what degree of correspondence exists between the information arriving at a node and the information leaving that node. Additionally, questions were designed to determine what information processing takes places within that node.

The first part of the questionnaire (Survey Questions 1-6) to traced the information flows within the pipeline, discovered what information is available to managers in the pipeline, and determined the respective roles of the managers in the pipeline. The second part of the questionnaire (Survey Questions 7-9) was intended to look more closely at the quality of information available to pipeline managers, and to identify problem areas in the information flow within the pipeline (Table 1). The following section links the investigative questions provided in Chapter I with the survey questions posed during the structured interviews (see Table 1).

Investigative Question 1. "What are the key agencies (nodes) in the physical movement of the gearboxes and how are they linked (arcs)?" - This question was not answered

TABLE 1

SURVEY QUESTIONS

1. What paperwork/computer printouts/forms/online information/verbal information do you receive?

2. Where does this information come from (office symbol/point of contact) and by what medium (mail/telephone/autodin/fax/etc.)?

3. What pieces of information do you use to manage on a regular basis and how do you use them?

4. What paperwork/computer printouts/forms/online information do you produce or add to and send on?

5. Where do you send this information (office symbol/point of contact) and by what medium (mail/telephone/autodin/fax/etc.)?

6. What tasks do you perform on a regular basis(daily, weekly, monthly)?

7. Does the information you receive help you to manage the assets in the pipeline?

8. How could this information be improved in terms of content, accuracy, or frequency to help you to manage more effectively?

9. What problems do you experience in managing the information that passes through your office?

by a specific survey question, but through a series of unstructured telephone interviews

Investigative Question 2. "What are the key agencies (nodes) in the information flow and how are they linked (arcs)?" - This question was answered by Survey Questions 2 and 5.

Investigative Question 3. "What standard forms/computer inputs and products are used to track assets through the pipeline? - This question was answered by Survey Questions 1, 3, and 4.

Investigative Question 4. "What are the respective roles of the key managers in the pipeline?" - This question was answered by Survey Question 6.

b Investigative Question 5. "Are the available information products useful tools for managers in the pipeline?" - This question is answered by Survey Question 7 and 8.

Investigative Questions 6-8. "What problems exist in the interface between the Air Force and Navy supply systems for H-53 gearboxes?", "What problems exist in the interface between the Air Force and Army supply systems for H-60 gearboxes?", "What problems exist in the transfer of information within Air Force logistics channels?" - These questions are answered by Survey Question 9.

Actual Data Collection Method

The first stages in the data collection process involved preliminary unstructured telephone calls, designed to establish tentative pictures of the pipelines and acquire a working knowledge base from which the researcher could develop relevant questions. This step corresponds to what Emory calls the "exploratory" stage of the interview study, where unstructured questions and responses are appropriate (10:206). The incremental approach of extending out from a node was used at this point. The Demand Processing section of Base Supply at a using unit's host base was chosen as a starting point.

The first stages were an iterative process of increasing refinement of the pipeline map. The physical movement maps were relatively simple to construct. The information flow maps, however, were far more complex. To a certain extent they followed standard supply requisitioning routes, but as stated in Chapter I, each pipeline has its own unique components and these pipelines with their interservice interfaces had some particularly unique components. Additional complexity was introduced into the information flow maps because the information flow contained both elements of supply requisition processing and elements of management control. That is, some information is used to process the request (drive the "order cycle"), and some information is used to manage assets and track them through the pipeline.

After establishing a tentative picture of the pipelines and acquiring a knowledge base from which to develop questions, the questionnaire was used to confirm presumed links in the pipeline, determine the role of each player in the pipeline, and compare input and output at each node.

Selection of the Research Population

Basic Description. The first criterion for choosing interviewees was that they appeared from the initial unstructured research to be a key player in the pipeline. The vast majority of the interviewees were chosen not only because they had a role in information processing in the pipeline, but also because they were managers and decisionmakers who controlled the movement of assets in the pipeline.

Categories of Interviewees. The interviewees were divided into three basic categories: users, requisition processors, and asset managers. Users are maintenance supervisors who initiate the repair cycle by assigning a "nonrepairable - this - station (NRTS) code" to a reparable asset, based on their determination that the asset is beyond their organic repair capability. Requisition processors are those individuals involved in the actual processing of the supply requisition. Finally, asset managers are those individuals who oversee, make decisions about, and control the movement of assets through the repair cycle.

Rationale for Selection of Individual Interviewees. This research effort involved interviews with a very large number of individuals who have a role in the repair cycles for these two gearboxes. The following individuals are key players from each category, who provided the bulk of the information presented. Figure 5 illustrates the position each of these individuals fills in the sequential flow of information within the two repair cycles addressed. The following individuals are key users in the repair cycle:

Master Sergeant Marlin D. Smith, 1550 OMS/MAOFH - MSgt Smith is the H-53 Branch Chief at the 1550 Organizational Maintenance Squadron, 1550 Combat Crew Training Wing, Kirtland Air Force Base, New Mexico. With an inventory of eight H-53 helicopters and a mission of special operations training, the 1550 CTTW is a representative H-53 owning unit. MSgt Smith is responsible for all organizational level maintenance on the 1550th's H-53 fleet and, as such, is intimately involved with H-53 main gearbox malfunction analysis, base level condemnation(NRTS) determinations, and decisions to cannibalize a gearbox in the face of an unacceptable supply status. Interviewed by telephone.

Master Sergeant Ronnie E.Hancock, 1550 OMS/MAOFM - MSgt Hancock supervises organizational maintenance on the fleet of H-60 helicopters owned by the 1550 Combat Crew Training Wing, Kirtland Air Force Base, New Mexico. In this role he is able to provide insight into the impact of main gearbox availability on the availability of H-60 helicopters

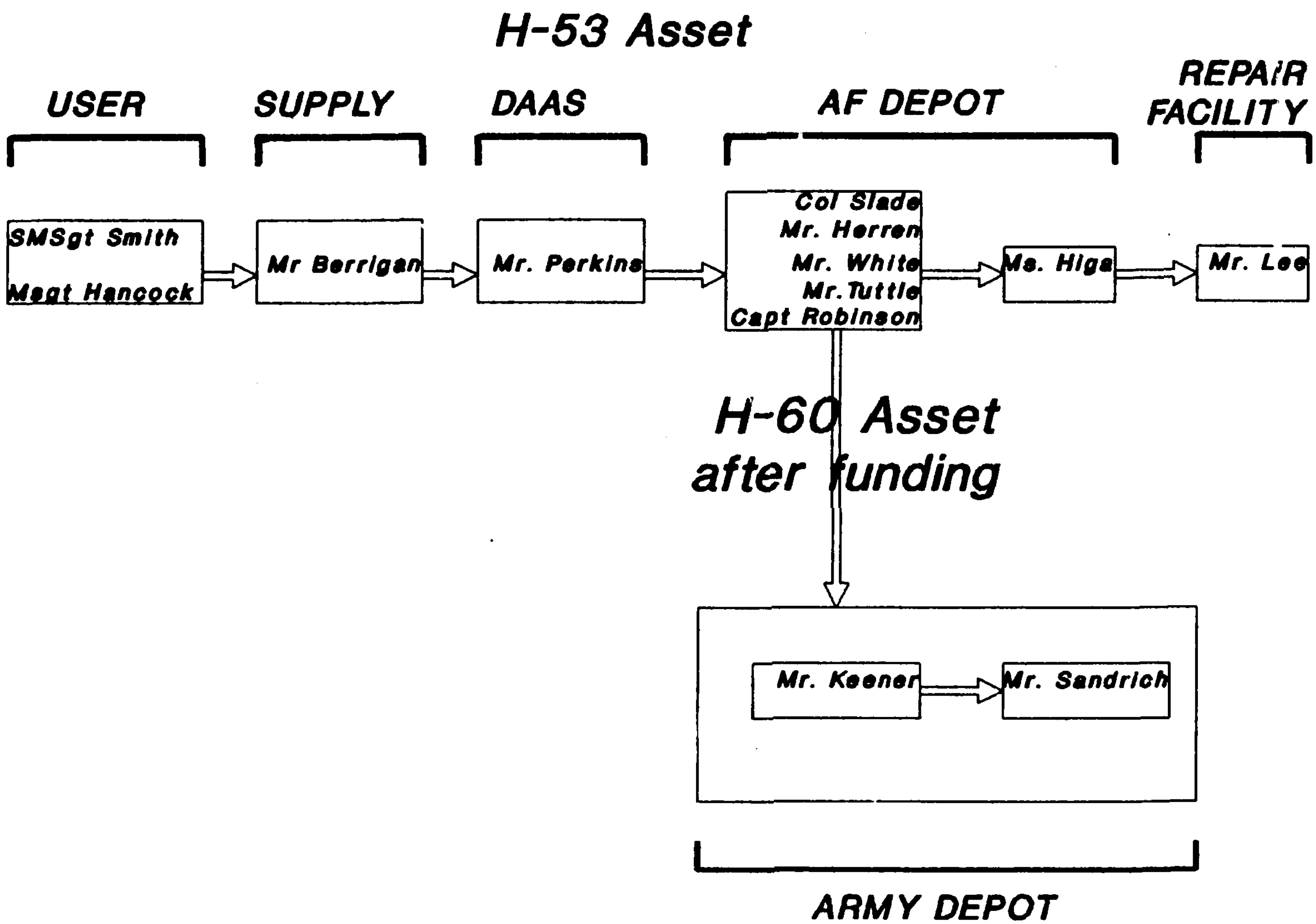

Figure 5. Interviewee Position in Repair Cycle

comparable to that provided by MSgt Marlin for H-53 availibility.

The following individuals are key players in the supply requisitioning process for H-53 and H-60 helicopters:

Mr. Berrigan, 1606 ABW/Demand Processing - Mr. Berrigan is one of the first people at the Base Supply servicing the 1550 CTTW to receive the supply requisition for an H-53 main gearbox. He is exactly one step away in the pipeline from the using unit. Interviewed by telephone

Mr. Perkins, DAASO/VLL - Mr. Perkins is responsible for the bank of computers at Gentile Air Force Station, Ohio that perform electronic quality control on supply requisitions routed through that station on their way to their respective source of supply. In the case of H-53 main gearboxes, this is Warner Air Logistics Center and in the case of H-60 main gearboxes, it is AVSCOM, the Army equivalent of Headquarters Air Force Logistics Command. Interviewed by telephone.

The following individuals are key managers in the H-53 and H-60 Main gearbox repair cycle:

Col Slade, WR-ALC/MMO - Col Slade is Head of Special Operations Logistics at Warner-Robbins Air Logistics Center, Robins Air Force Base, Georgia. In this capacity, he is the overall manager for logistics support on all SOF weapon systems. Interviewed by telephone.

Mr. John Herren, WR-ALC/MMOMH - As the H-53 System Program Manager, Mr Herren is responsible for all logistics support of H-53 helicopters. As such, he is the key player on the H-53 team of SOF Logistics. Interviewed in person.

Mr. Earl Tuttle, WR-ALC/MMOMH - Mr. Tuttle is the Air Force System Program Manager for the H-60 Helicopter, managing all its logistics support. Interviewed in person.

Capt Robinson, WR-ALC/MMODC - Capt Robinson is the Chief of the Customer Support Branch under SOF Logistics. Capt Robinson and his individual weapon system specialists track the status of priority requisitions on all SOF weapon systems. Interviewed in person.

Mr. Earl White, WR-ALC/MMODJ - Mr. White is the item manager for NSN 1615-00-468-0566, the H-53 gearbox. Through the DO41, Requirements Computations, files maintenance cycle, he intensively manages repair requirements for the H-53 main gearbox. Additionally, he maintains asset visibility via AFLC Form 47, Asset Reconciliation-Investment Items. Interviewed in person.

Sandra Higa, WR-ALC/MMOPS - Ms. Higa is the Buyer Production Management Specialist for the Depot Maintenance Service Agreement(DMISA) between the Air Force and Pensacola Naval Aviation Depot. As such, she administers the agreement and is the primary liason between the item manager and the depot repair operation at Pensacola.

Mr. Jeff Lee, "Progressman" for H-53 main gearbox overhaul, Pensacola Naval Aviation Depot - Mr. Lee is Ms. Higa's primary point of contact at Pensacola. He tracks the progress of the gearbox overhaul and is able to provide Ms. Higa with an Estimated Delivery Date which is then provided to the SOF Customer Support Branch through Mr. Earl White, the Item Manager. Mr. Lee provides the most first hand level of visibility within the depot repair facility. Interviewed by telephone.

Respondent Cooperation.

The researcher found the respondents to be almost unaminously supportive of the research effort. In many cases, they would suggest a specific person in another agency, usually their point of contact, that would be an especially cooperative and fruitful source of information for the researcher. To further increase the value of the telephone interviews in particular, the researcher attempted to establish rapport with the respondents. Emory advocates this approach: "Good rapport is useful in building respondent interest in the project and the more interest the respondents have, the more cooperation they will give(10:211)." He further points out, "It behooves the business reseacher using telephone surveys to attempt to improve the enjoyment of the interview(10:171)." This researcher found that following Emory's advice greatly facilitated the research effort and strongly advocates its use by other reseachers performing interview studies.

Summary

This chapter has discussed the methodology used to answer the research questions posed in Chapter I. This methodology consisted of unstructured and structured interviews, by telephone and in person; and review of relevant reports, forms, and regulations. The construction of the maps of the physical movement and information flows was based on an incremental method of tracing out from a known point. The next chapter will present the findings obtained using these methods.

IV. Findings

Introduction

This chapter presents the end products of this research effort. The first set of end products are the flowcharts depicting the physical movement of assets through the repair cycle along with a brief written description of the processes. The second set of products are the flowcharts depicting the information flows through the two pipelines and their associated written descriptions. The basic information flows for MICAP requisitions are supplemented by flowcharts depicting specific management information flows within the depot at Warner Robbins Air Logistics Center along with the written description of these processes.

Physical Movement of Assets

The answer to the first investigative question, "What are the key agencies (nodes) in the physical movement of the gearbox and how are they linked (arcs)?" was obtained through unstructured telephone interviews. Two physical movement flowcharts are presented, one for H-53 main gearboxes and one for H-60 main gearboxes.

Unserviceable H-53 main gearboxes are shipped directly from the using units via government truck, commercial truck, Logair, military airlift, or a combination thereof, to the repair facility at Pensacola Naval Aviation Depot,NAS Pensacola, FL. The same modes are used to transport serviceable gearboxes back to the using units (Figure 6). Gearboxes coming to and from the 667th Consolidated Aircraft Maintenance Squadron(CAMS) at RAF Woodbridge utilize military airlift through RAF Mildenhall. The 1st Special Operations Wing (SOW) at Hurlburt Field, Florida has the unique advantage of being within a short drive by government truck from the repair facility. According to Mr. Ray Buck, the Weapons Systems Logistics Officer assigned to the 1 SOW, it takes longer to move serviceable gearboxes around at the Navy depot than it does to move them to Hurlburt Field(6).

An offshoot to this relatively simple flow is created by the diversion of serviceable gearboxes from the helicopters undergoing various modification and inspection programs at the repair facility at Pensacola. These programs are: the Service Life Extension Program (SLEP), the Aircraft Condition Inspection (ACI), and the modification of H-53 helicopters to a special operations configuration(PaveLow modification) (18). This practice amounts to a cannibalization action performed to fill requisitions for aircraft grounded for lack of a gearbox (MICAP requisitions). The requirement on the donor aircraft must then be filled with an asset off the repair line. These diversions take place on a recurring basis.

The fact that there are only two H-60 units in the Air Force makes the physical movement chart for the H-60

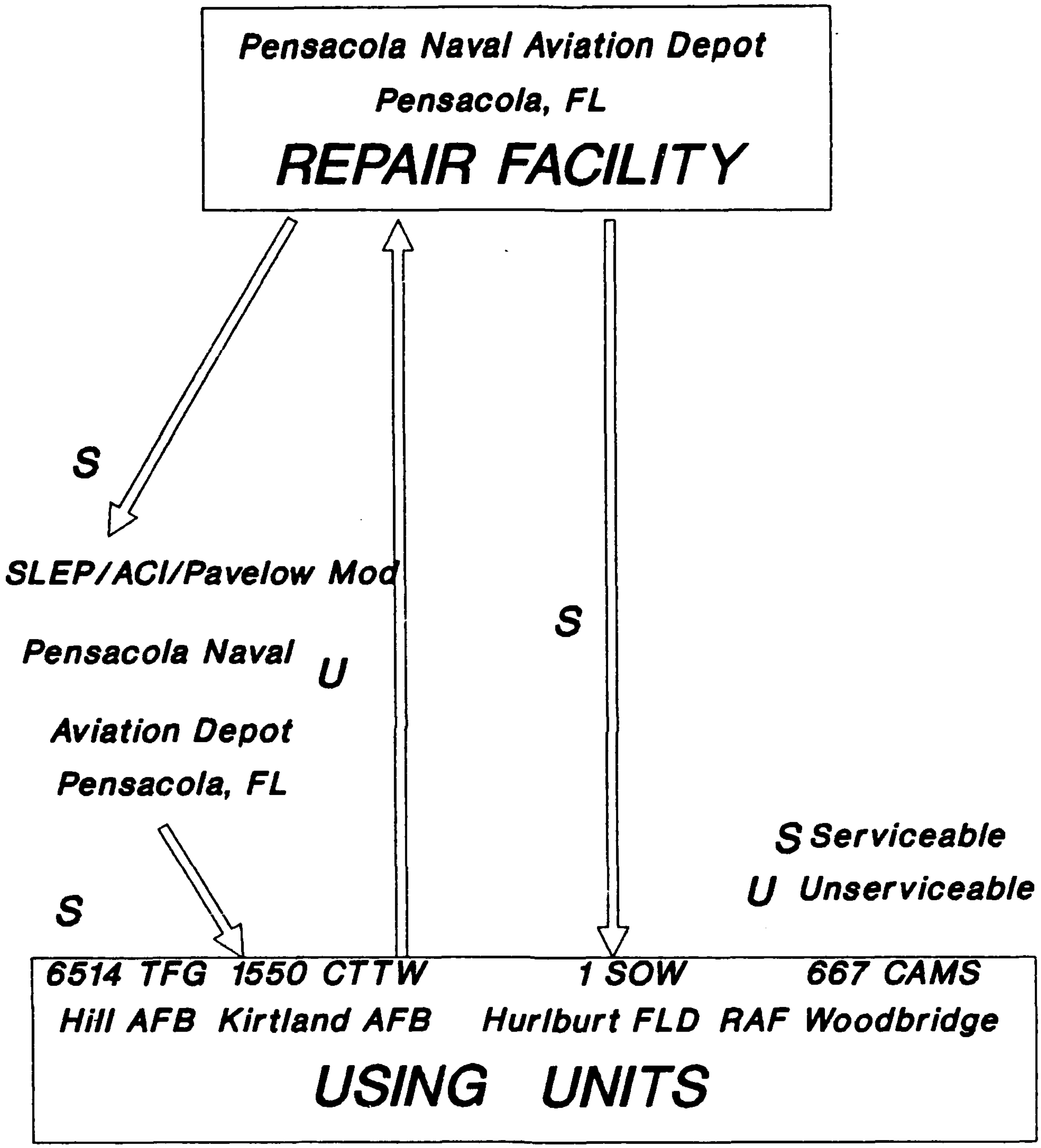

Figure 6. H-53 Gearbox Physical Movement

gearboxes somewhat simple (Figure 7). Additionally, diversion from modification aircraft is not used to fill H-60 main gearbox MICAP requirements (39). Although there is presently an Army pilot program to develop an organic overhaul capability at Corpus Christi Army Depot (CCAD), Corpus Christi Naval Air Station, Texas, it was omitted from of the flowchart because of its minimal output. The primary repair facility for H-60 main gearboxes is at the Sikorsky Products Division, Stanford, CT. All unserviceable H-60 gearboxes bound for Sikorsky are routed through the Army's Lexington Bluegrass Depot Activity at Lexington, Kentucky . Serviceable gearboxes returning to the using units are routed through New Cumberland Army Depot in New Cumberland, Pennsylvania (21).

Information Flows

MICAP Requisition for Repair. The information flow for the repair cycle of a helicopter main gearbox, whether H-53 or H-60 begins with the determination that the gearbox needs to be sent from the using unit, either for repair or for overhaul. If the gearbox requires depot level repair, this determination is the first management decision in the repair cycle and is made by an experienced technician, usually a senior noncommisioned officer with extensive expertise on the weapon system (Figure 8). The Branch Chiefs interviewed, one an H-53 branch chief and one an H-60 branch chief, both indicated that they personally make this

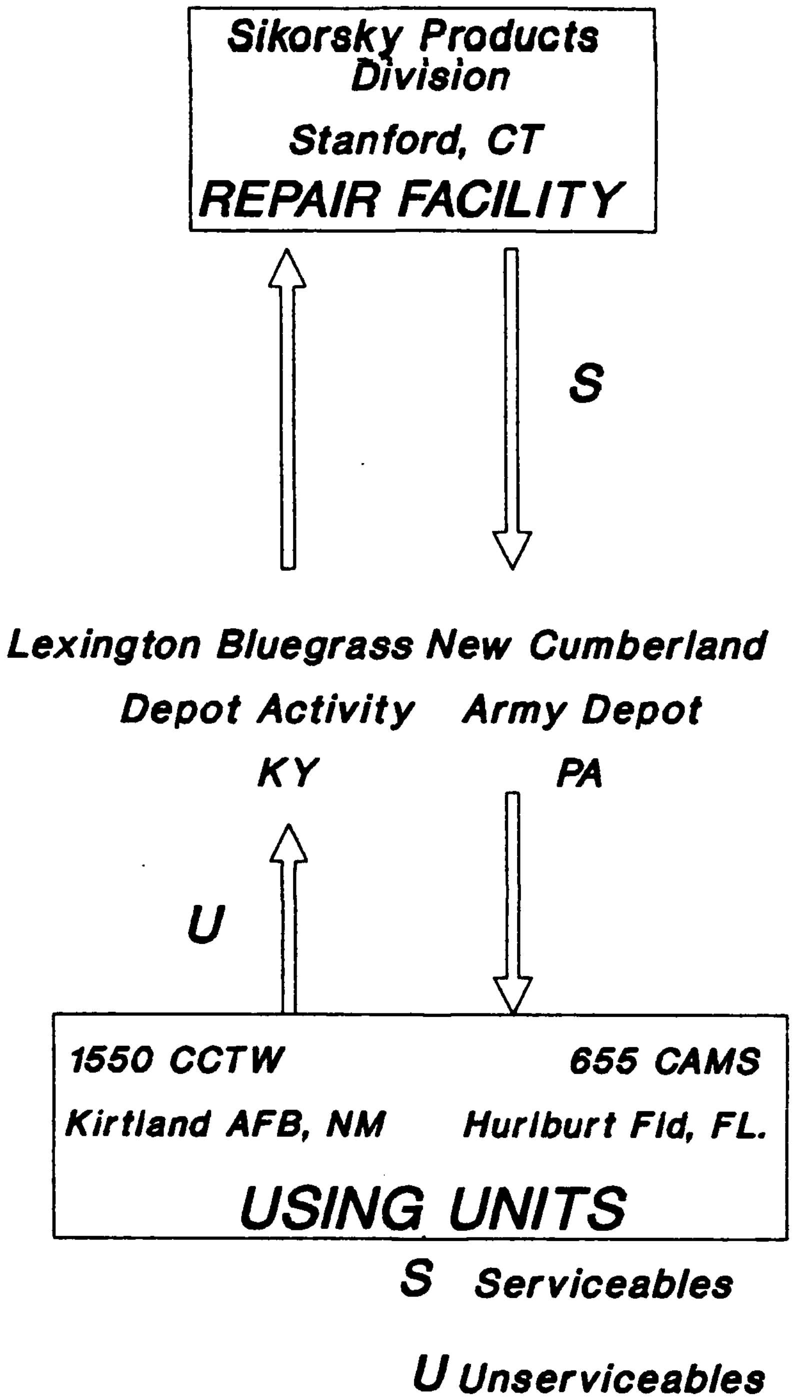

Figure 7. H-60 Gearbox Physical Movement

REASON FOR INITIATION: REPAIR

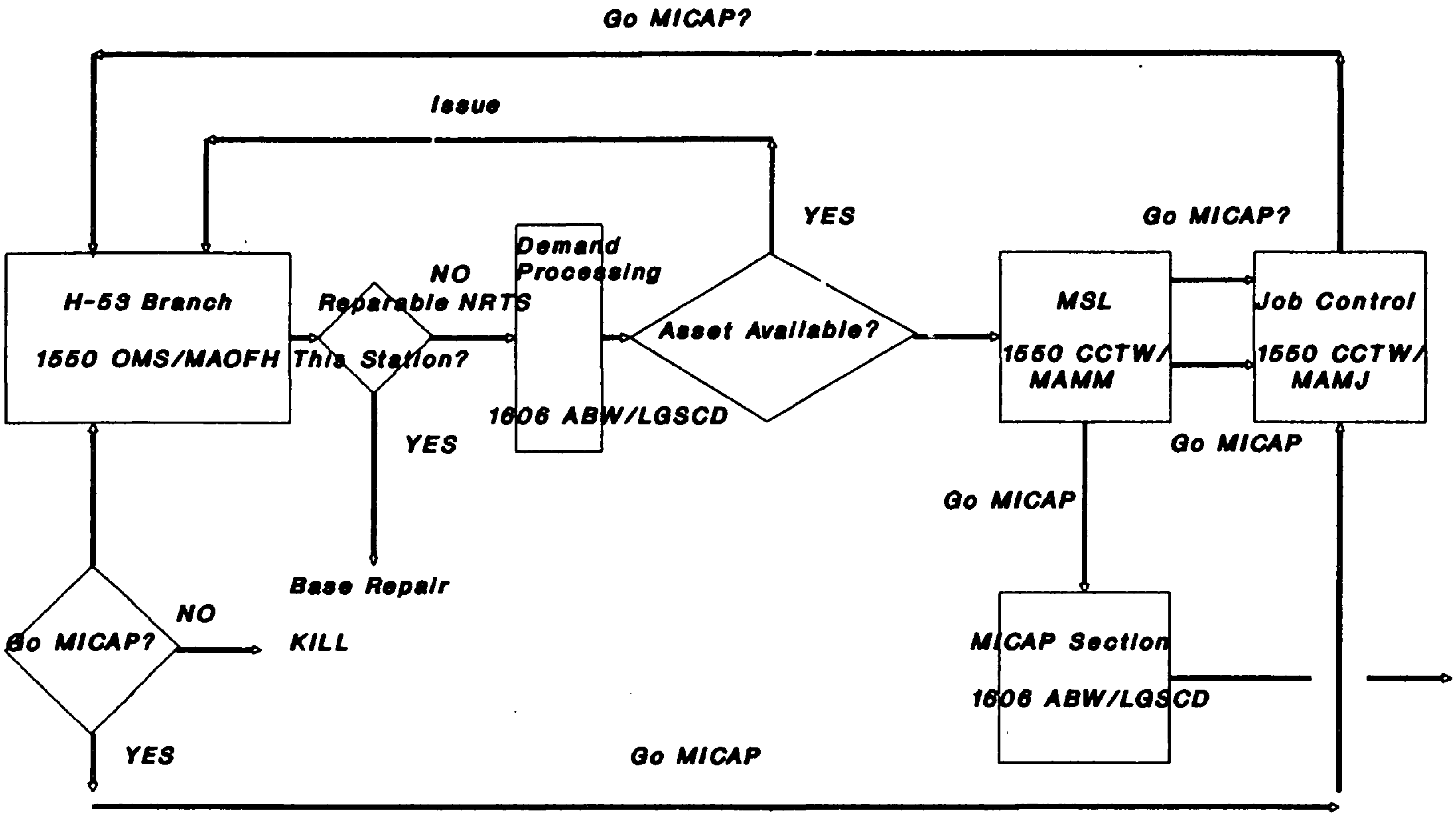

Figure 8. MICAP Requisition for Repair

decision (6 & 15). This individual determines that the nature of the malfunction renders the gearbox Not-Repairable-This Station (NRTS), that is, beyond organic repair capability. This determination is indicated by attaching two copies of DD Form 1572-2, the "NRTS tag", to the gearbox after it is removed from the aircraft. The NRTS tag, along with identifying information for that specific gearbox, also contains a brief description of the malfunction (15).

Immediately after the NRTS decision and prior to processing of the unserviceable gearbox, a new gearbox is ordered through the Demand Processing section of Base Supply. This is the beginning of the order cycle. It immediately follows the initiation of the repair cycle , asmentioned in Chapter II. Base Supply then performs a search for available assets. If this search does not reveal an available asset on base, Maintenance Supply Liason(MSL) at the unit is notified. MSL in turn notifies the maintenance unit of the asset nonavailability on base and then asks whether the part in question is necessary for flight. If this is the case, the aircraft would be a Non Mission Capable, Supply status and the part would be backordered at this point (29).

Because the gearbox is critical to helicopter operations, the absence of a gearbox mandates an NMCS condition for the asset. As a result, requisitions for H-53 and H-60 gearboxes are of the highest priority -- MICAP.

One of the individuals in the unit with authority to verify MICAP conditions must make the decision to order the gearbox on the highest supply priority appropriate to that unit. The alternative is to cannabilize the gearbox, usually from an aircraft that is already non-mission capable with a long lead time, either because it requires extensive maintenance (Non Mission Capable Maintenance, NMCM), has a part or parts on order with a distant estimated delivery date(Non Mission Capable Supply, NMCS), or both(Non Mission Capable Both, NMCB). Often this may be an aircraft undergoing a periodic inspection. If the decision is made toor declare a MICAP status, will again, almost always be made at the senior noncommisioned officer level. If the decision is made to declare a MICAP status, Demand Processing passes the requisition by hard copy to the MICAP section within Base Supply (2).

Initial Routine Requisition for Overhaul. The second cause for gearboxes entering the repair cycle is scheduled overhaul (Figure 9). Frequencies are loaded in the maintenance management information system in use at that unit. Within this system, an automated records check (ARC) is performed on a daily basis to update the number of flying hours and subtract them from the number of hours till overhaul for that gearbox. A weekly review of the ARC is performed to coordinate and plan for replacement of parts coming due for time change (for overhaul, in this case)

REASON FOR INITIATION: OVERHAUL

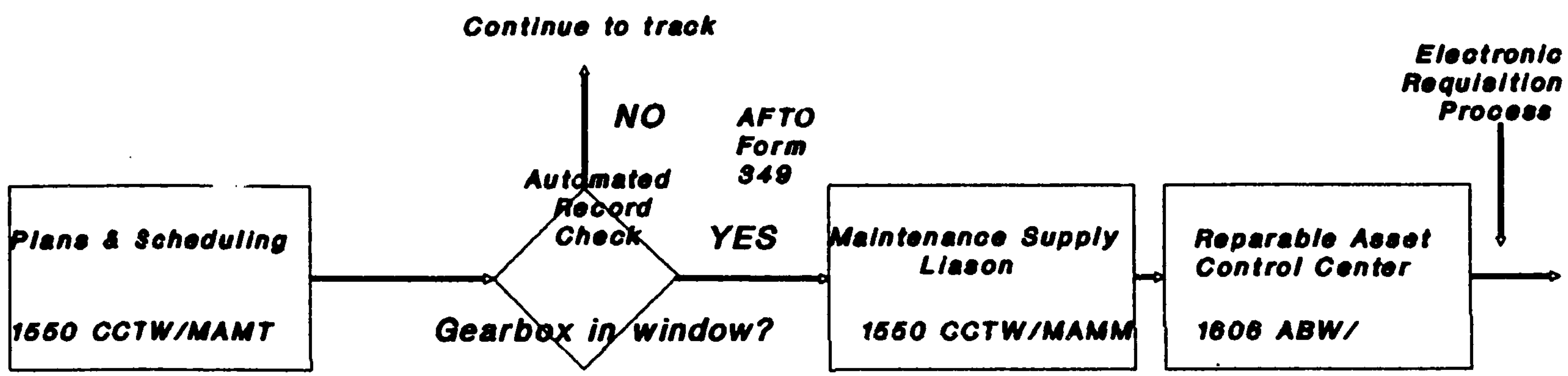

Figure 9. Initial Routine Requisition for Overhaul

during the projected window for the next periodic inspection.

The actual mechanics of the planning involves projecting the aircraft's historical average of flying hours per day to estimate when it will be due its periodic inspection and then doing a similar projection to determine what parts will be due time change within the window that stetches 100 hours on either side of the projected periodic inspection input date. If a part falls within this window, it is scheduled for time change during that periodic inspection (38). The responsible individual in Plans and Scheduling will then order all parts scheduled for time change during that periodic inspection, 60 prior to the projected inspection input date. These parts are ordered by submitting a maintenance management system generated AFTO Form 349, Maintenance Data Collection Record, indicating the requirement for time change. MSL, in turn submits a DD Form 2005, Issue/Turn-in Request to the Reparable Asset Control Center at Base Supply, requesting a routine requisition of those parts.

MICAP Upgrade of Overhaul Requirement. If the main gearbox is one of these scheduled parts and the Estimated Delivery Date given as part of its backorder status indicates that it will not arrive in time to be changed during that inspection, a second decision point has been reached (Figure 10). If the gearbox is being scheduled for time change for the first time, it can be extended beyond

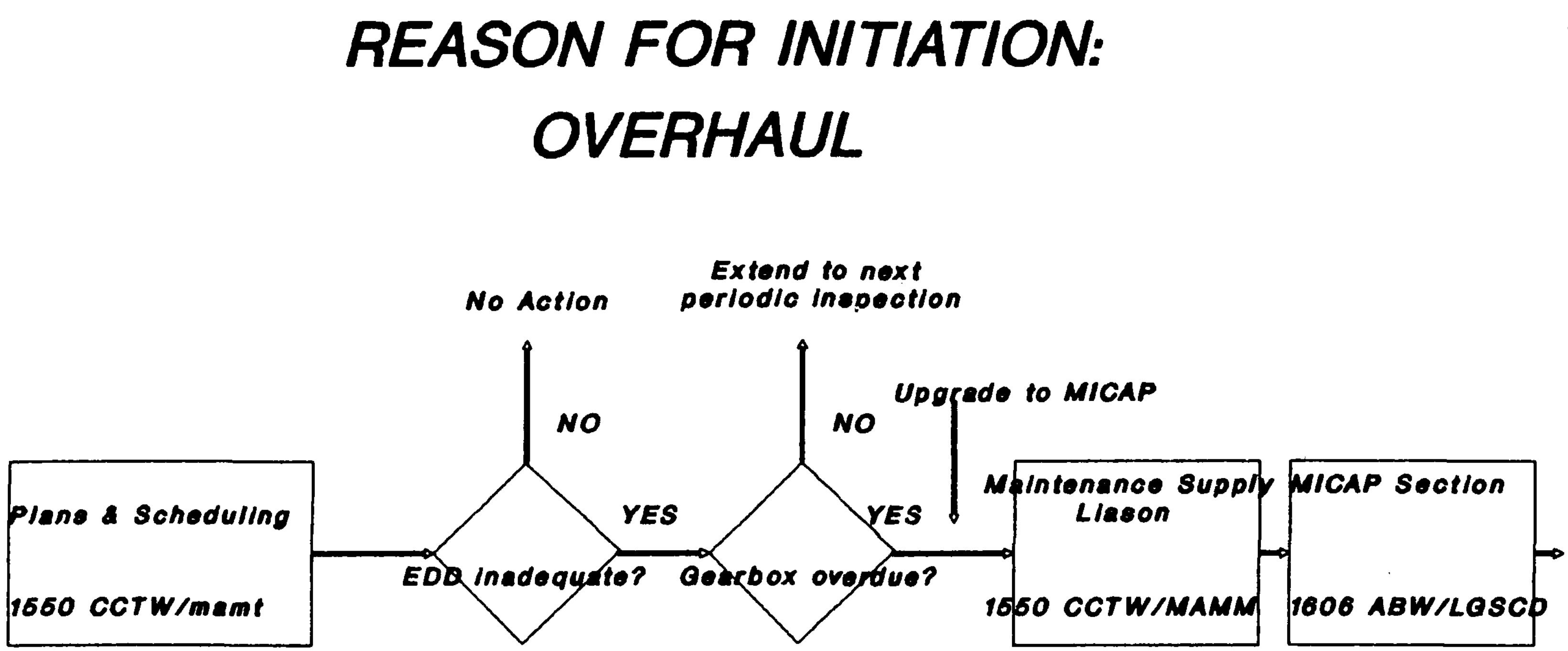

Figure 10. MICAP Upgrade for Overhaul

its normal time change point, continue to be flown, and will then be scheduled for time change during the next periodic inspection. If, however, it is already overdue inspection, that is, it has already been extended once, it must be changed during this coming inspection. In this case, at a point 14 days out from the scheduled inspection input date, the responsible individual in Plans and Scheduling will notify MSL to upgrade the requisition to a MICAP priority (16 & 38). Having brought the requisition into the MICAP section via its two initiation channels, the discussion will now cover the processing of a MICAP requisition for an H-53 or an H-60 main gearbox.

On Base MICAP Requisition Transmission For ease of explanation, the following discussion will be in terms of a MICAP requisition for an H-53 or H-60 gearbox comming from Kirtland Air Force Base,New Mexico (Figure 11). In the MICAP section of Base Supply, an individual will enter the MICAP requisiton on a formatted screen at a terminal connected to the supply computer system. From this terminal, in the case of a MICAP requisition submitted at Kirtland Air Force Base, New Mexico, the requisition will be routed through one of two remote terminals in the Remote Processing Station of the 1606th Base Supply to the receiving computer at the 1606th Communications Squadron (2 & 45). Four times a day, the automatic address program in this computer runs through the files in which the requisitions are located and generates a transmission tape,

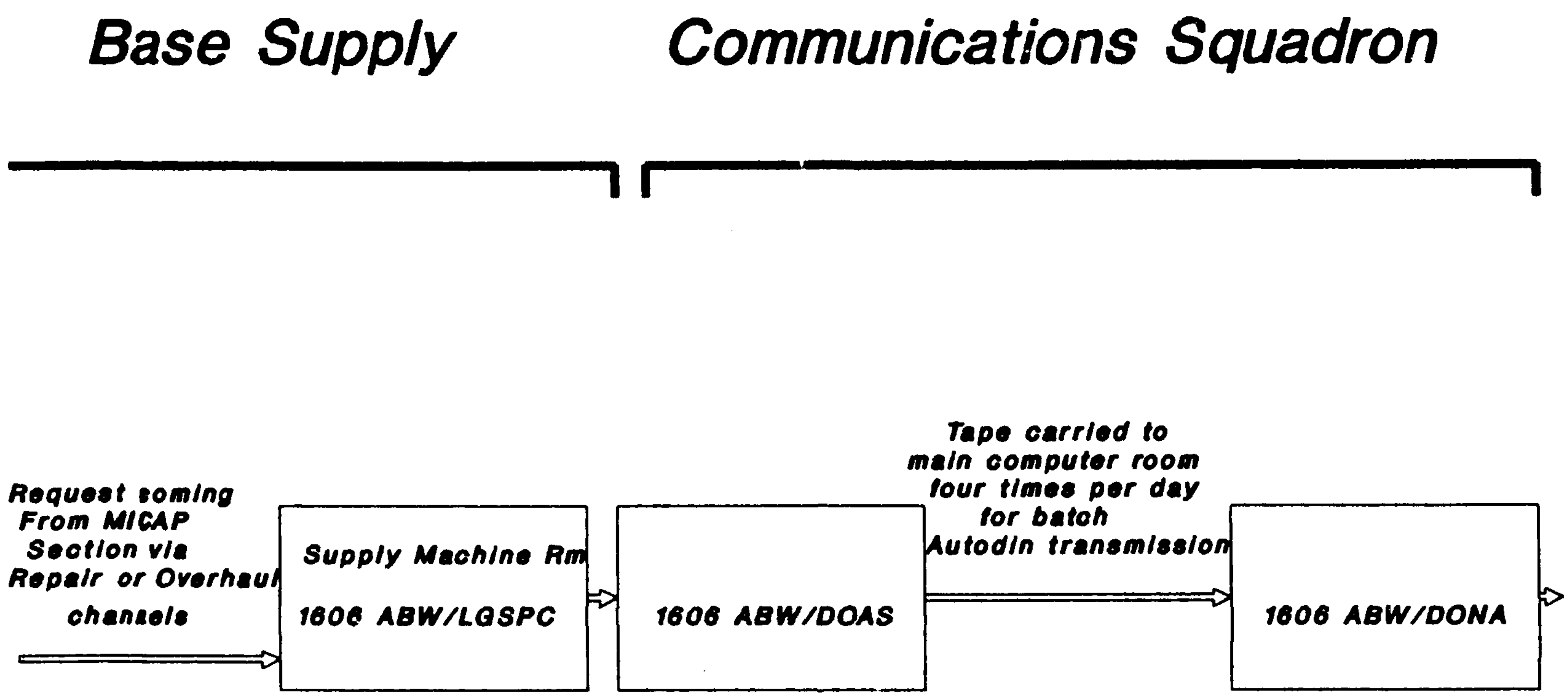

Figure 11. On Base MICAP Requisition Transmission

which is then hand- carried to the transmission computer. The computer makes a batch transmission over AUTODIN lines (24).

MICAP Requisition up to Depot Receipt Since these MICAP transmissions are coded as logistics transmissions, they are routed through the Defense Automatic Address System (DAAS), a special electronic transmission system dedicated to logistics traffic (Figure 12). DAAS has eight identical switching stations, designed for redundancy. Four are located at Tracy Air Force Station, California and four are located at Gentile Air Force Station, Ohio. Requisitions bound for Warner-Robbins Air Logistics Center(WR-ALC), Robins Air Force Base, Georgia from Kirtland Air Force Base, as would be the case for H-53 and H-60 requisitions, would be routed through Gentile AFS, Ohio. These switching stations perform what is essentially a quality control function by an automatic computer process that detains the requisition for approximately 10 minutes, as it waits in queue to be batch transmitted after being processed. The actual processing is virtually instantaneous. The computer checks the format of the requisition against built-in integrity standards. If there are formatting errors, the requisition is automatically retransmitted to the originating base. If the format is correct, the requisition is passed on to the appropriate inventory control point (31).

For H-53 parts, WR-ALC is the Primary Inventory Control Point (PICA). The item managers for all H-53

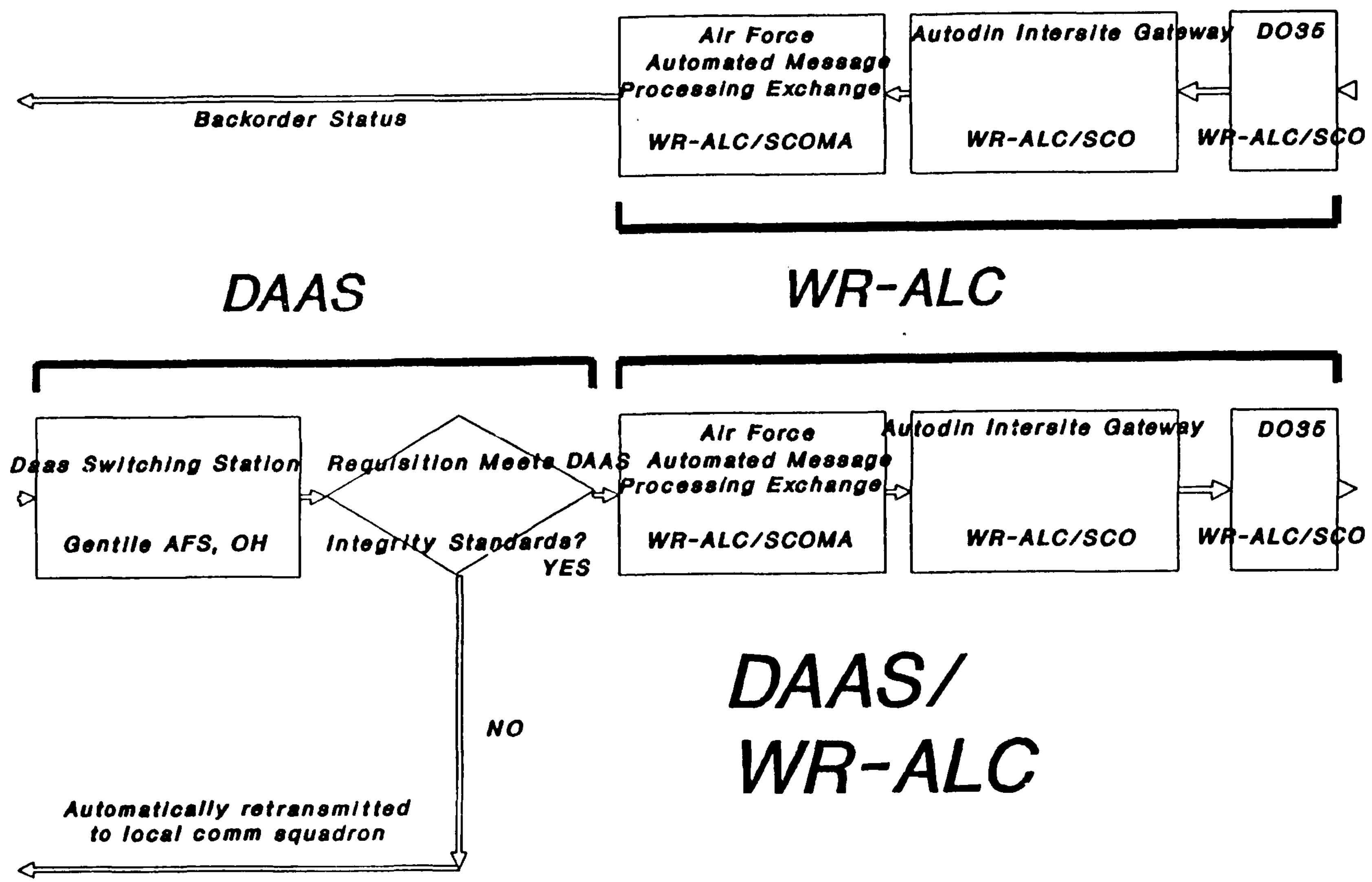

Figure 12. MICAP Transmission up to Depot Receipt

peculiar parts are located at WR-ALC. The item manager (IM) is responsible for controlling and managing the inventories of the parts he/she manages and possesses the broadest visibility over those parts of any manager involved with them. In the interest of maintaining a smooth, sequential flow, the discussion will continue to trace the primary information flow of a MICAP requisition through the repair cycle and then return later to a discussion of the information flow within the PICA.

Once on Robins AFB, the AUTODIN message arrives first at the Air Force Automated Message Processing Exchange. From there it is passed through the AUTODIN Intersite Gateway to the D035 supply computer system (Figure 12)(17). The D035 sytem does an automatic search of the source of supply inventories to determine if an asset is available for release. For H-53 main gearboxes, the Source of Supply is the centalized storage facility for H-53 parts at Hurlburt Field, Florida, the home of the the only user of H-53 helicopters with an operational mission, the 1st Special Operations Wing (1SOW) (43). Another reason for centralizing storage of H-53 main gearboxes at Hurlburt Field is its close proximity to NAS Pensacola, previously noted in the discussion of the physical movement of the gearboxes.

<u>MICAP Processing - WR-ALC/Source of Supply</u> If an asset is available at the storage facility, the D035 passes a material release order (MRO) to the source of supply,

directing it to release an asset and ship it to the base supply squadron at the using unit host base (Figure 13). At this time, the source of supply will also transmit a shipping status and Estimated Delivery Date (EDD) to the appropriate supply squadron, which will, in turn, provide this status to the using unit. If an asset is not available, the computer will now check to see if this item is a Manager Review Item and, if it is, what Manager Review Item code the IM has loaded against the item. This code basically indicates the degree of direct control which the IM wishes to maintain over the part in question. In the case of an H-53 main gearbox this code is an "X", indicating that the D035 computer should automatically release all available assets, but refer all backorder requisitions (no asset available at the source of supply) to the Item Manager (8).

When the D035 system refers a requisition to the IM, he/she will receive a notification on their D035 screenon the terminal at their desk. It is now the responsibility of the IM to locate an asset and release it to the requisitioning unit. The IM's search begins with an attempt to locate an excess asset at another base that can be pulled to fill the MICAP requirement. The IM has two computer accessed listings to assist with this search. The first is the Worldwide Inventory/Supply Information Management System (WISMIS) D087 report. The D087 will

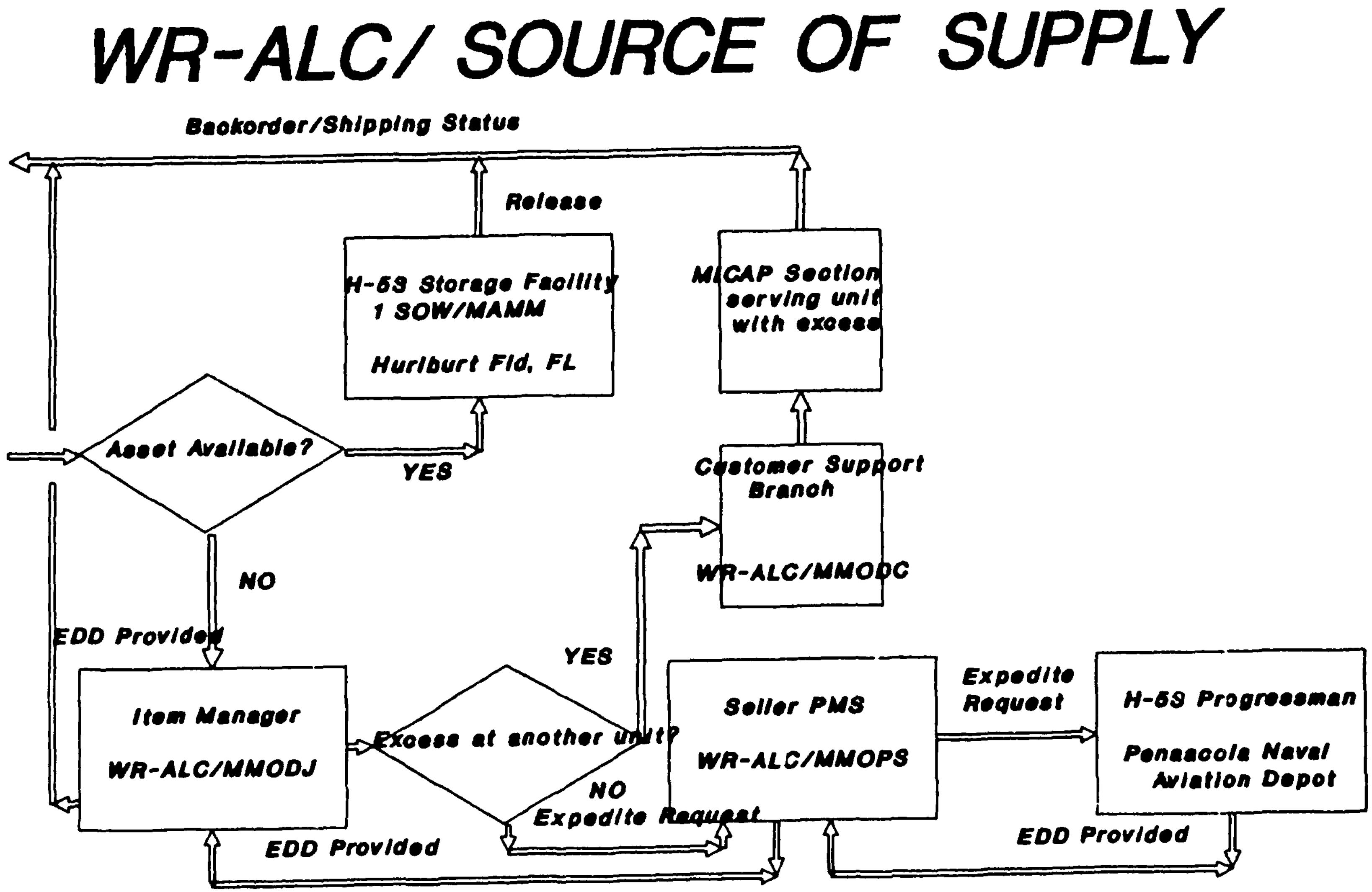

Figure 13. MICAP Processing - WR-ALC/Source of Supply

give the IM the location worldwide of any available gearboxes. The other listing is the D143H system-generated -52A report, the Tight Item List. The Tight Item List provides information similar to the D087 (43).

Once the IM has located an available asset at another base, he/she must request permission to pull this asset for lateral support. This request is processed through the Customer Support Branch of the Special Operations Forces (SOF) Logistics directorate of which the IM is a part (Figure 13). The Customer Support Branch, in turn, makes its request for a redistribution of the asset via a telephone call to the MICAF section of the unit possessing the asset (35). If the IM is unsuccessful in the effort to locate an asset at another unit, the next step is to submit a request for expedited repair to the depot repair facility at Pensacola. This request is made via a telephone call to the Seller Production Management Specialist (PMS) at WR-ALC. This is consistent with the Seller PMS role as a liason for actual contract compliance between the Air Force and the contract repair facility. The Seller PMS will make the expedite request by telephone to the Component Manager at the Military Interservice Coordination Office at Pensacola. The Component Manager then will submit the request to the H-53 Progressman exercising direct monitoring and control authority over the repair/overhaul operation. The backflow of information involves communication of an Estimated Delivery Date, via telephone, backward through the same sequence of agencies (19).

<u>H-60 Requisitions through Army Channels</u> In the case of an H-60 MICAP requisition entering the Army supply system, there is no processing at WR-ALC other than the assignment of an Air Force fund code as the requisition passes through the D035 computer (Figure 14) (Tuttle). After leaving WR-ALC via the Autodin system, the requisition passes again through the DAAS switching station. It is then passed on to the Aviation Systems command (AVSCOM), St. Louis, Missouri, a part of the Army Material Command. At AVSCOM, the first determination made by their equivalent of the D035 computer is whether the item is an Army Intensive Management Item (AIMI). If the answer is "No", the item is automatically released or backordered by the computer without managerial intervention. If the answer is "Yes", the requisition is automatically downloaded offline via a hard copy, which is received by the Distribution section at AVSCOM. If the Distribution manager of that item has an asset available, he/she releases that asset. If there is no asset available, the requisition is held in the computer in a prioritized listing. As assets become available and the Distribution manager is made aware of their availability by the Item Manager, the Distribution manager releases assets according to the prioritized listing supplemented by the Distribution manager's personal judgement (23).

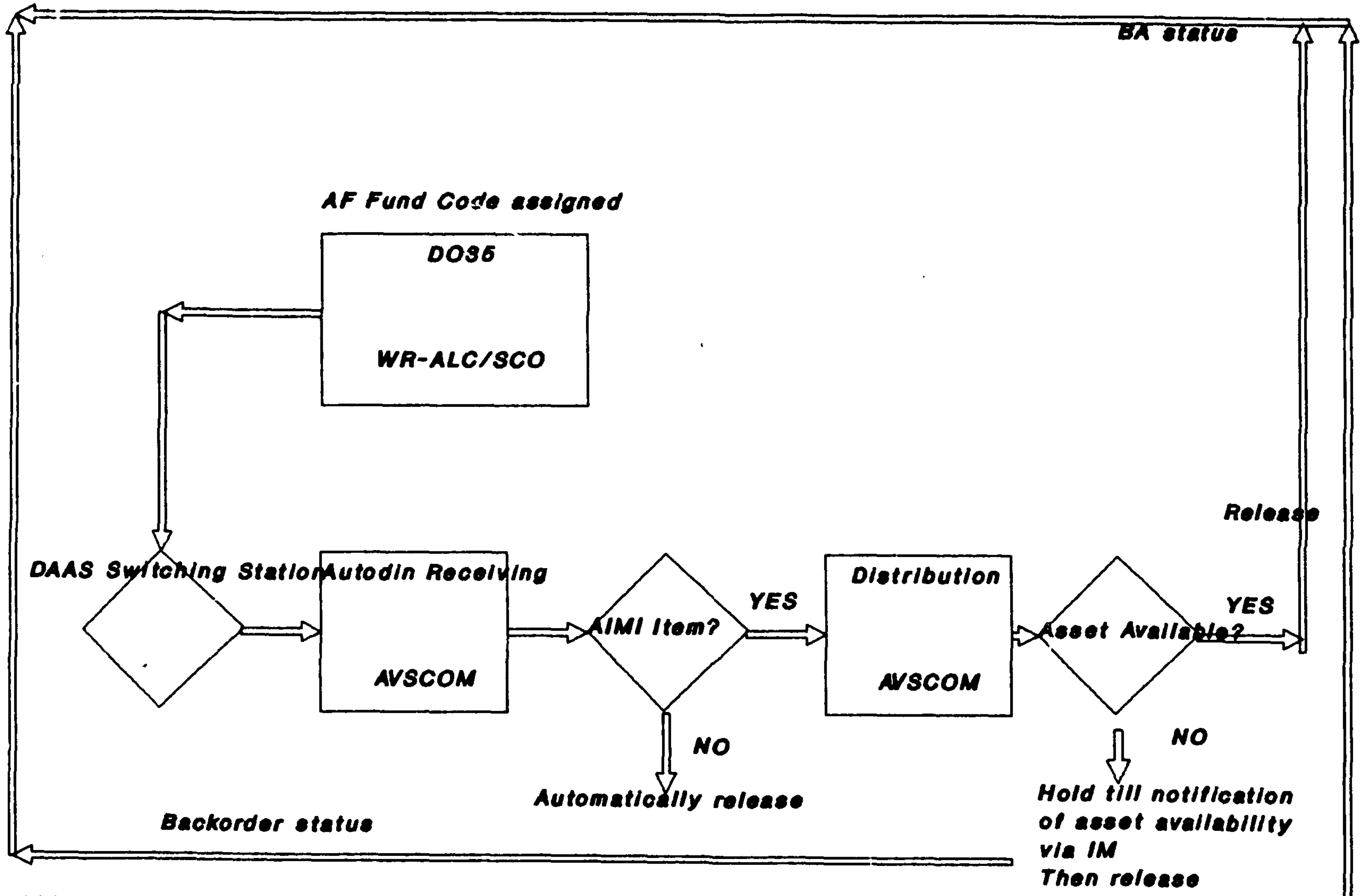

Figure 14. H-60 Requisitions through Army Channels

Depot Level Interventions. The first two management flows to be examined are associated with actions that constitute direct management interventions into the normal stream of requisitioning and repair cycle events. Of these two actions, the first to be discussed involves the requisitioning process. The initiation of this management intervention is a telephone call or message from the MICAP section of Base Supply a base that has requisitioned a given SOF-peculiar part (Figure 15). In either case, a hard copy message must always be submitted. This request for supply assistance comes first to the Customer Support Branch in SOF Logistics. The system manager in the Customer Support Branch will then call the relevant IM.

If, as in the case of H-53 main gearbox, the only available assets are those coming off the depot repair line, the IM will contact the Seller PMS, who will pass the request for expedited repair to the H-53 Progressman by telephone with a hard copy to follow. The Progressman will then analyze the present and projected course of the repair or overhaul, determine what actions would be required to expedite the completion of depot maintenance, direct those actions be taken, and provide an Estimated Delivery Date for the expedited repair to the Seller PMS. The Seller PMS now relays this EDD back through the IM to the Customer Support Branch manager who provides it back to the using unit (25).

DEPOT MANAGEMENT

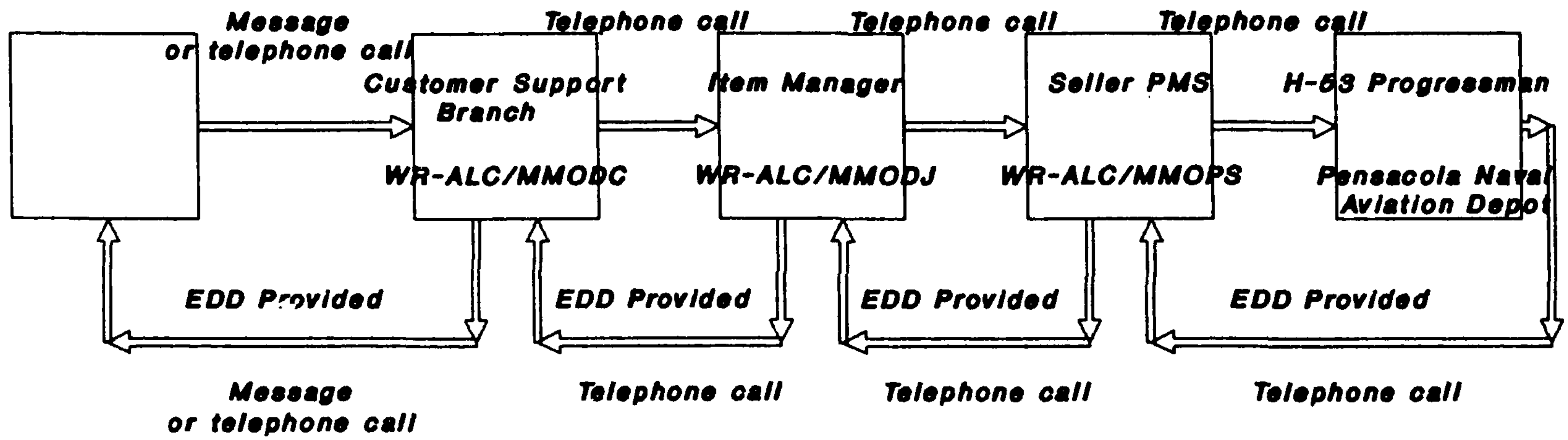

Figure 15. Customer Support Branch Intervention

The second type of management intervention is the System Program Manager directed diversion of an asset off an aircraft that is presently out of commission for an extended time period while undergoing either a modification, an upgrade program, or an extensive periodic inspection (Figure 16). In this case, the Maintenance Control Officer, usually an O-5, from a using unit, calls the SPM and requests that a helicopter in one of the above listed categories be cannibalized to meet a MICAP requirement. Often the aircraft to be cannibalized belongs to the unit making the request. The SPM will in turn complete a locally produced request for cannibalization and forward it to the Maintenance Interservice Coordination Office (MICO) at Pensacola. The MICO personnel then pass the request to the H-53 Progressman who insures the task is carried out (18).

Annual and Monthly Production Management. The actual development of a depot repair schedule and its periodic adjustment is the central management process in the H-53 main gearbox repair cycle. The development of a depot repair cycle is designed to meet projected repair requirements based on programmed flying hours. Its development and adjustment are the product of close coordination between the Item Manager, the Seller PMS, and the MICO office (Figure 17). In late August/early September, the Item Manager submits a D073-X21 Intermediate Range Projection Worksheet to the Seller PMS. The calculations for this worksheet are based on the detailed

DEPOT MANAGEMENT

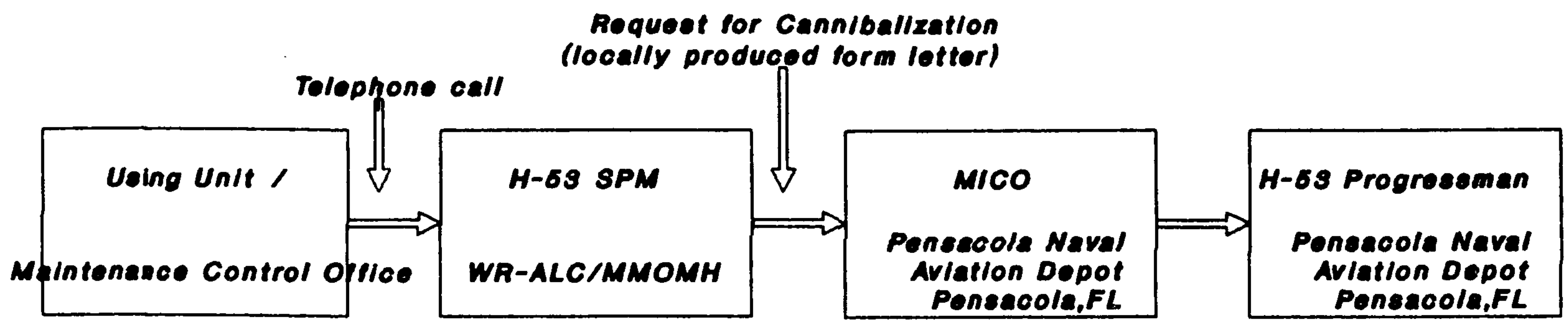

Figure 16. SPM-Directed Diversion

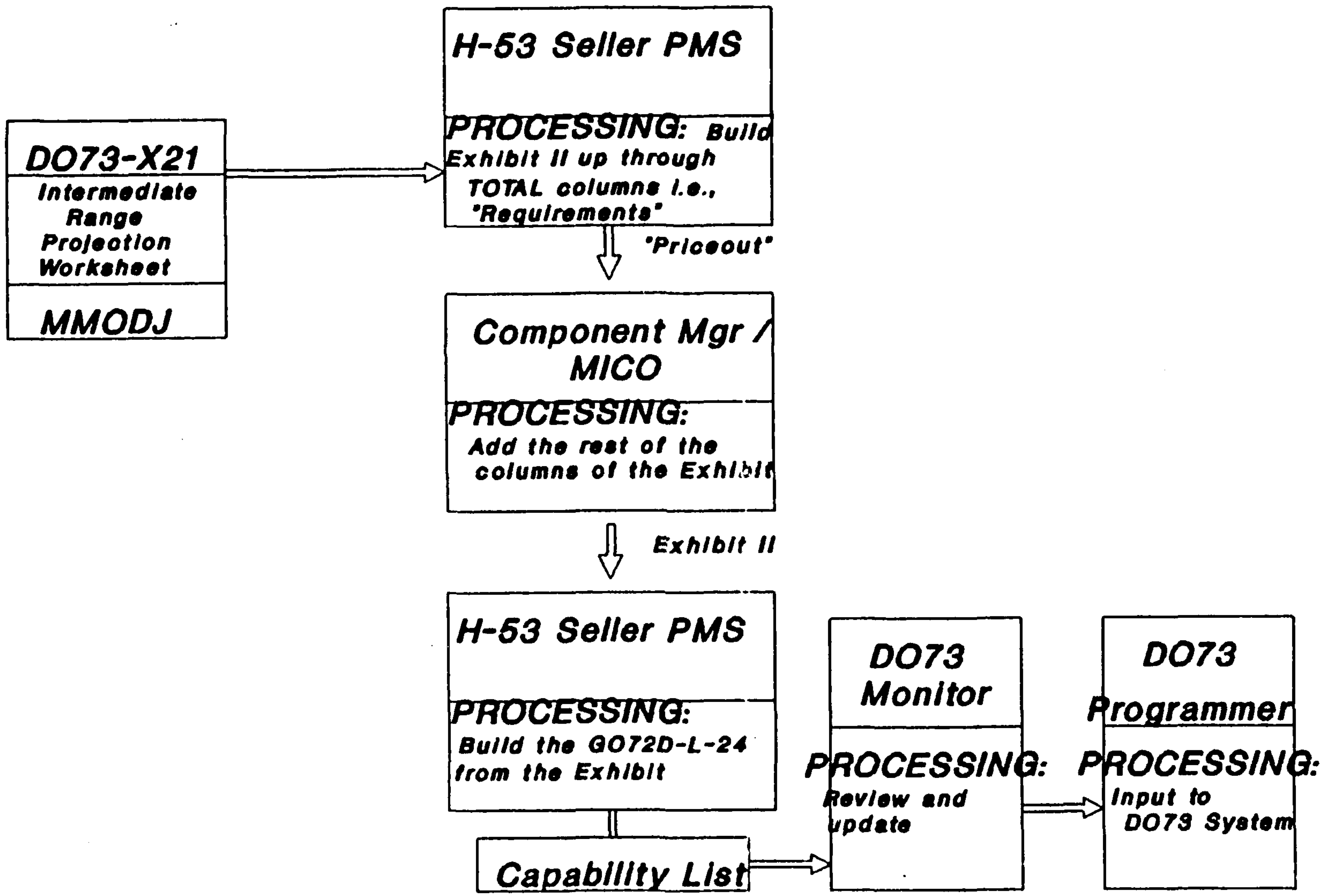

Figure 17. Annual Production Management

database and computational capabilities of the D041 Recoverable Consumption Items Requirement System. The Seller PMS uses the X21 Worksheet with its projected repair requirements to input the required production schedule on to Exhibit II of the Depot Maintenance Interservice Agreement (DMISA). The DMISA is the contract between the Air Force and the Navy depot repair facility (21).

The Component Manager at MICO takes the Exhibit II and, based on the requested repair schedule, calculates and adds costs along with the required manhours and flow time through the depot expressed in days. Exhibit II is used in turn by the Seller PMS to build the G072-L24 Capability List, which is passed with its now approved and agreed upon production schedule to the D073 monitor, who passes it after review and update to the D073 programmer for input to the D073 system (21).

The Seller PMS also ensures accurate tracking of depot production by using the AF Form 413, Depot Maintenance Production Report, to adjust the G072D-L37, Contract Visibility List (21) (Figure 18).

Summary

This chapter presented the end products that resulted from the research program outlined in Chapter III. Chapter V will summarize the thesis and present the recommendations for action and further study that this research effort yielded.

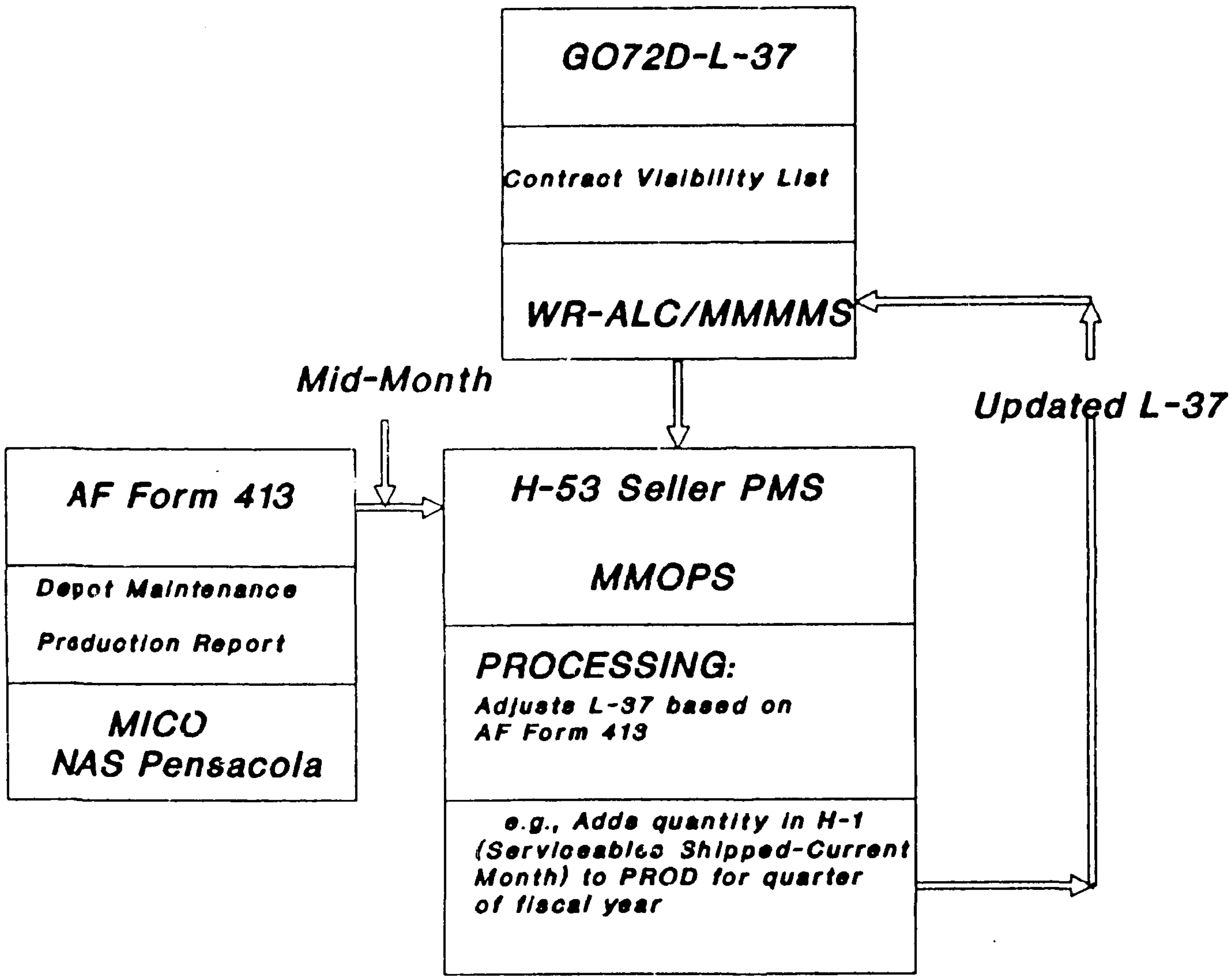

Figure 18. Monthly Production Management

V. Analysis and Recommendations

Introduction

This research effort set out to accomplish a portion of the AF/LE tasking to "collectively piece together what information is regularly collected and used by managers." It focused on one portion of the pipeline, the repair cycle. This focus was justified by the central role of the repair cycle in the pipeline for a reparable part. This study looked at the repair cycles for comparable components found on two different weapon systems - the main gearboxes on the H-53 and H-60 helicopters. As critical weapon systems supporting special operations, the Air Force mission with the highest likelihood of initiation in the near future, the H-53 and H-60 helicopters warranted attention. As high dollar cost components, repaired and/or managed outside Air Force logistics channels, the H-53 and H-60 main gearboxes were good candidates for specific focus. This study successfully traced the physical movement and information flows within these repair cycles as the first step in understanding the pipelines, both as specific pipelines and as representative pipelines for reparable components. The ultimate goal is to shorten these pipelines and, thereby, increase the availability of the weapons systems they support.

Overview

Chapter I established the tasking for this research effort, introduced the basic concept of a logistics pipeline, and explained the focus of this study. Chapter II explained pipelines in systems terminology, illustrating the central role of the repair cycle in the pipeline for a reparable part and reviewing the literature on repair cycles. The chapter then discussed the order cycle and its impact on the repair cycle, closing with a review of recent periodical literature on the importance of speeding order processing time. Chapter III explained the methodology used to conduct this study. This methodology, based primarily on personal interviews, was supplemented by an examination of relevant management reports and governing regulations. Chapter IV presented the basic end products of this research effort: maps of the physical movement and information flows within the pipeline with narrative explanations. This chapter will present the final end product of this research, a analysis of the quantity and quality of onformation available to managers in the pipeline, supplemented by a discussion of the problems noted by managers within the pipeline. It will also offer recommendations for improving the efficiency and effectiveness of the pipeline and recommendations for further research in this important area.

Quantity and Quality of Information Available to Managers

Organizational Level Managers. Both the quantity and quality of information available to make management decisions vary from one level to another in the management of the repair cycles for H-53 and H-60 main gearboxes. There is also a fair degree of variation between the pipelines for the two gearboxes. Those individuals who are most sensitive to fluctuations in the customer service performance of the repair cycle are the supervisors at the organizational level. Accept for those with a logistics background (although their numbers are growing), parts availability is to a large extent invisible to flying operations managers. They are, in fact, the ultimate customers of the logistics system. However, whether an aircraft is available because the required part arrived at, or close to, its EDD; or whether maintenance personnel worked overtime postponing other important tasks, to cannibalize the part based on an inadequate EDD only to have it arrive the next day, is, justifiably, not a priority concern of the flying squadron commander. If the two repair cycles examined here are judged on their customer support of the maintenance manager who needs the part to fix the aircraft, they have some inadequacies. At the user level, two out of three of the users interviewed felt that the supply system did not provide them with sufficiently accurate information to make daily management decisions. Both the H-53 and H-60 Branch Chiefs at

Kirtland AFB complained of having, more than once, made a decision to cannabilize a main gearbox to get a needed aicraft in the air based on a distant EDD, only to have the asset delivered the next day (17,39).

Depot Level Managers The H-53 managers at Warner-Robins Air Logistics Center in general have access to a broad range of information sources. The Item Manager, in particular, can access a network of integrated and complimentary databases and computational programs from the D035 terminal on his/her desk. The face-to-face interviews with the H-53 main gearbox IM, Mr. Earl White, lasted a total of approximately four hours and only began to cover the most basic capabilities of the systems with which works. The interview provided a rudimentary understanding of the management processes he performs on a daily, quarterly and annual basis. This was despite his thorough knowledge of these processes and willingness to explain them in depth to the researcher.

The Item Manager's most powerful tool in exercising control over the repair cycle is the Recoverable Consumption Items Requirement System (D041). The D041 is a multi-faceted database and computational system. It plays its primary role in repair cycle management via the X-21 Intermediate Range Projection Worksheet, a product of the Repair Requirement Computation System (D073), an interfacing system to the D041 system. The combination of data overlaid from the systems that interface with the D073 system and the manual inclusion of actual repair facility production data by the IM, enable the IM to forecast next quarter's repair requirements using the previous quarter's historical data, updated by current figures (45).

One data source that appeared at first to provide specific empirical information about pipeline parameters was the Depot Repair Cycle Data, available within the D041 system and maintained in the D-143 series systems. These various parameters correspond to the AFLCR 57-4 components of the repair cycle discussed in Chapter II. Although the researcher made no thorough investigation into this area, it appears the overlay of information from the various D-143 series systems that collect and store this information is not entirely successful. On one D041 product observed during the personal interview with the IM, all but two parameters utilized standard data rather than empirical data. When an attempt was made to develop a distribution of reparable item transportation times, based on 10 quarters of average data, the total number of shipments per quarter was either three or four in all 10 quarters. The lack of variation expressed in this data seemed questionable. Additionally, the number of shipments and total days used to compute the average days per shipment was identical for three consecutive quarters. These observations taken together led the researcher to question the accuracy of this data.

H-53 Item Manager identified two problems that made his job more difficult. In both cases, the root cause of the problems was beyond his control. The first problem was the delinquent delivery of refurbished main gearboxes from the Sikorsky Products Division. This problem was echoed by the H-53 System Program Manager, Mr. Herren, and the H-53 Seller Production Management Specialist, Ms. Higa. The first of these of gearboxes was scheduled for release in October 1988 and, thereafter, at a rate of two per month. In anticipation of this schedule, WR-ALC had contracted for a total of just two gearboxes to be repaired/overhauled by Pensacola in Fiscal Year 89. When it was finally determined that Sikorsky would not be able to meet their production schedule, it was necessary to renegotiate the contract with Pensacola (21). At the time of the interviews with WR-ALC personnel in July 1989, the first gearbox had still not been released from Sikorsky. This chain of events played an important role in the present situation where every Air Force H-53 gearbox completing repair/overhaul at Pensacola is shipped against a MICAP requisition (26,46)

The second problem identified by Mr. White was subcomponent shortages at Pensacola. Mr Herren corroborated this and noted that the repair/overhaul operation at Pensacola and the refurbishment operation at Sikorsky both compete for the same limited inventory of subcomponents from a limited group of vendors (45,20). Mr Herren suggested greater visibility of the vendor sources for these subcomponents, would facilitate his management of the H-53 gearbox repair cycle. Enhanced visibility is complicated by Sikorsky's treatment of vendor sources as proprietary information. This subject of subcomponent management will addressed again in the discussion of Army depot level management of H-60 gearboxes.

The establishment of the SOF Logistics function at WR-ALC was a major step in organizing the management of the logistics processes, including the repair cycle for all SOF-peculiar items with the exception of H-60 components. Even for H-60 components, WR-ALC is the Secondary Inventory Control Point (SICA). Col Slade, the SOF System Program Manager, pointed out that in the past the existing matrix management system created problems with cooordination. Additionally, items peculiar to SOF weapon systems were managed by five different Air Logistics Centers. Since the establishment of SOF Logistics all SOF-peculiar items have, on an attrition basis, been transferred to IM's at WR-ALC. This process is virtually complete at this point (38).

On the subject of management information, Col Slade stated he utilizes a diversity of information products, some of them standard and some developed at his direction. He specifically cited funds management products, item management products, and Maintenance Data Collection (MDC) products. Of these, he pointed to funds management products as the most timely and MDC products as the least accurate. He offered a number of suggestions for improvement in the data he receives. In the area of content, he expressed a desire for more visibility at the repair/overhaul facility level. He cited accuracy of MDC data and unit reporting of MICAP requisitions as a problem. In general he expressed a desire for more real time information (38).

Army Depot Level Management The most obvious and significant trend in management of the repair cycle at the AVSCOM depot level is the Army focus on management at the subcomponent level. Maximizing the number of subcomponents that are Government Furnished Material (GFM) was stated as a prime management goal by Mr. Sandrich, the Sikorsky contract liaison at AVSCOM. Mr. Sandrich's fulfills a role similar to that of the Seller Production Management Specialist at WR-ALC. A secondary goal then becomes insuring the repair/overhaul facility at Sikorsky is provided with a full stockage of GFM (35).

Recommendations

Based on the insight gained through this study, the researcher recommends three actions be taken. First, a study should be made of the D143 series data collection procedures. The potential for obtaining valuable empirical data, inherent in these systems, is not being fully realized. If the D-143 system could actually capture, analyze and store data that could be converted to accurate pipeline paramaters, this information could be used to provide a quantitative picture of the pipeline. Such an action would facilitate the next step in pipeline analysis. The admittedly superficial observations of this study indicate possible problems with the accuracy of this data.

Secondly, Air Force adoption of a subcomponent management system at depot level, similar to that in place at AVSCOM should be investigated. Col Slade, Mr. Herren, and Mr. White, managers at three succesive levels of management within SOF Logistics, all point to lack of visibility and control over subcomponents crucial to gearbox repair/overhaul as a major impediment to effective repair cycle management.

Finally, consideration should be given to establishing a distribution manager or a distribution management team for critical items like H-53 and H-60 main gearboxes. At present, no one person has the overall viewpoint that would eliminate suboptimization and increase overall efficiency of the pipeline. Such an individual or team would possess at the very least the type of perspective provided by this study. Additionally, they should be armed with a quantitative picture of the pipeline that includes the time in days, periodically updated for each leg of the repair cycle.

Recommendations for Further Study

In addition to studies suggested by the concerns expressed above, the researcher suggests the following as possible topics for further study:

The Air Force should conduct a study of cannibalization, lateral support, and diversion as methods of filling a MICAP requirement. We need to understand what we pay in terms of dollars and additional pipeline days for these various methods of filling a MICAP requisition.

Research should follow a datum or group of data as they move through the information flows to determine how they are manipulated along their journey. This study would examine data accuracy. The Depot Repair Cycle Data captured by the D-143 series systems or an EDD are possible candidates for a study of this type.

A researcher should conduct a study of Item Managers to determine how these key logistics managers do their jobs. The IM has been identified elsewhere in this study as the one individual most intimately involved with the pipeline for a reparable item under his/her control. The Item Manager's job is highly complex and cannot be effectively perfomed without the development of a high level of resource management skill and insight. This wealth of knowledge should be investigated, analyzed and recorded.

An attempt should be made to assign actual times to the arcs of the pipeline delineated in this study - It was beyond the scope of this study to acquire this valuable data, vital to understanding and ultimately shortening the pipeline for these reparable components. This study was intended as the first step in understanding the behavior of a reparable asset in the military logistics pipeline. Identifying and collecting data to model the pipeline remains the subsequent step in the research stream.

Summary

This chapter shows there is an enormous amount of data captured and made available to managers via numerous databases. The full potential of this data to provide useful information to managers is not at this point being realized. In particular, this system often does not give the working maintenance supervisor the foresight needed to make simple day to day decisions. This information needs to be streamlined and focused and made more accurate so that i ealizes its maximum potential for usefulness.

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Vita

Captain David B. Noble [redacted] He attended Rutgers - The State University of New Jersey, graduating in May 1977 with a Bachelor of Arts in Psychology. In August 1977, he entered the USAF and in January 1979 received a commission through Officers' Training School. He completed the Aircraft Maintenance Officer Course at Chanute AFB, Illinois in July 1979 and was subsequently assigned as an aircraft maintenance officer at Detachment 10, F.E.Warren AFB, Wyoming. In October 1981, he was assigned to the Enroute Section of the 608th Military Airlift Support Squadron, Ramstein AB, Germany. Upon his return to the U.S. in October 1984, he was assigned to the 1550th Combat Crew Training Wing, Kirtland AFB, New Mexico. There he served as OIC, Job Control and 1550th Organizational Maintenance Squadron Maintenance Supervisor until entering the School of Systems and Logistics, Air Force Institute of Technology in May 1988.

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This study was designed to respond to an AF/LE tasking to examine the pipeline with the goal of determining what information was captured by the relevant databases and what data was used by managers within the pipeline. The study focused on the repair cycles for H-53 and H-60 main gearboxes. Repair cycles were chosen because they were determined to be the central and most significant portion of the pipeline in terms of management for a reparable component. There were three end products of this research: (1) Maps of the physical movement of assets through the repair cycle; (2) Maps of the information flows within the pipeline; (3) An analysis of the quantity and quality of information available to managers in the pipeline.

The study methodology was based on the assumption that a map could be traced by extending from a known point in the repair cycle and utilizing the knowledge of the individuals at that point. These individuals were assumed to understand the nature of their interactions with other agencies. It was assumed that by using this incremental method, a macro view of the repair cycle could be traced.

Personal interviews and review of relevant management reports and regulations were the specific techniques used.

The research was successful in obtaining its intended end products. Comprehensive maps of both the physical movements and the information flows were developed for both pipelines. Additionaly,an analysis of the quantity and quality of information was conducted. It was determined that despite the broad range of computer-accessed information available, the organizational level maintenance managers were still not provided the information they needed to facilitate their decision making. It was determined that a more effective use of existing databases was called.